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Glossary of Acronyms

A$	Australian Dollar
ACT	Australian Capital Territory
BEED Act	Building Energy Efficiency Disclosure Act
BOMA	Building Owners and Managers Association
BREEAM	Building Research Establishment Environmental Assessment Method
CBD	Central Business District
CSR	Corporate Social Responsibility
EEGO	Energy Efficiency in Government Operations
EER	[Australian Capital Territory] Energy Efficiency Rating
EPC	[European] Energy Performance Certificate
ESCO	Energy Service Company
EU	European Union
EUA	Energy Upgrade Agreement
EUI	Energy Use Intensity
GFC	Global Financial Crisis
IPD	Investment Property Databank
LEED	Leadership in Energy and Environmental Design
LEED O&M	Leadership in Energy and Environmental Design: Operations and Maintenance
MD	Mandatory Disclosure
NABERS	National Australian Built Environment Rating System
NCREIF	National Council of Real Estate Investment Fiduciaries
NLA	Net Lettable Area
NOI	Net Operating Income
NSW	New South Wales
NT	Northern Territory
PCA	Property Council of Australia
QLD	Queensland
SA	South Australia
TAS	Tasmania
VIC	Victoria
VIF	Variance Inflation Factor
WA	Western Australia

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Selected portions of Chapters 5 and 6 are forthcoming in an article for the Journal of Property Investment & Finance:

Gabe, J. and Rehm, M. (forthcoming). Do tenants pay energy efficiency rent premiums?" Journal of Property Investment & Finance, forthcoming.

Nature of contribution by PhD candidate	Literature review, extraction of raw data from NABERS Energy certificates and lease documents, final model specification, estimation of model, and writing of entire manuscript.
Extent of contribution by PhD candidate (%)	85%

CO-AUTHORS

Name	Nature of Contribution
Michael Rehm	Assisstance with lease contract acquisition, advice on initial model specification and equation estimation procedure, and review of manuscript drafts.

Certification by Co-Authors

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
- in cases where the PhD candidate was the lead author of the work that the candidate wrote the text.

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Last updated: 25 March 2013

Preface

In 2003, a large Australian pension fund, Local Government Super, chose to pursue what appeared to be an unconventional long-term investment strategy in four commercial office assets it owned. According to portfolio manager Brian Churchill, Local Government Super decided to take an ethical approach to investing; mitigate energy, water and waste costs; and procure best-practice environmental ratings (Churchill *et al.*, 2011). Eight years later, Churchill argued that an investment of A$3.9 million towards this strategy had yielded A$6.4 million in productivity benefits for tenants, some of which was expected to have been shared with the firm in the form of higher rent, although he did not present evidence that such a rent premium emerged.

It now appears this strategy was not unconventional at all for the Australian commercial office property market over the past decade. Other major asset owners also reported anecdotally that investment in natural resource efficiency had become integral to their business practices. For example, the 2011 Annual Report from the ING Property Fund shows that planned investment is inversely related to a NABERS [National Australian Built Environment Rating System] Energy rating, which measures the relative degree of energy efficiency in a commercial office asset (Figure P.1). And not all evidence was anecdotal. Newell (2008) undertook a thorough analysis on reports from Australian listed property trusts, finding a systematic desire to lead the implementation of environmental sustainability from a strategic viewpoint. In addition, the 2011 Global Real Estate Sustainability Benchmark study (Bauer *et al.*, 2011) found in their review of annual reports that nearly all of the “Global Environmental Leaders” in resource efficiency are Australian-based funds.

This thesis empirically examines the role that NABERS Energy assessments have played in this strategic transition to greater operational resource efficiency in Australian commercial office property markets. A structural outline is presented in Figure P.2. After Chapter 1 discusses the relevant literature, Chapter 2 introduces the context of Australian commercial office property markets, the NABERS Energy rating system, and the country’s history of green building interventions. Chapters 3 and 4 address two research questions related to “environmental effectiveness”, or the effect of NABERS Energy certification on the energy consumption of existing Australian office assets. Chapters 5 and 6 present a discourse related to the market effects of NABERS Energy on rent prices paid by tenants in central Sydney. Chapter 7 concludes with a summary of research findings, their implications for the property industry and future research needs.

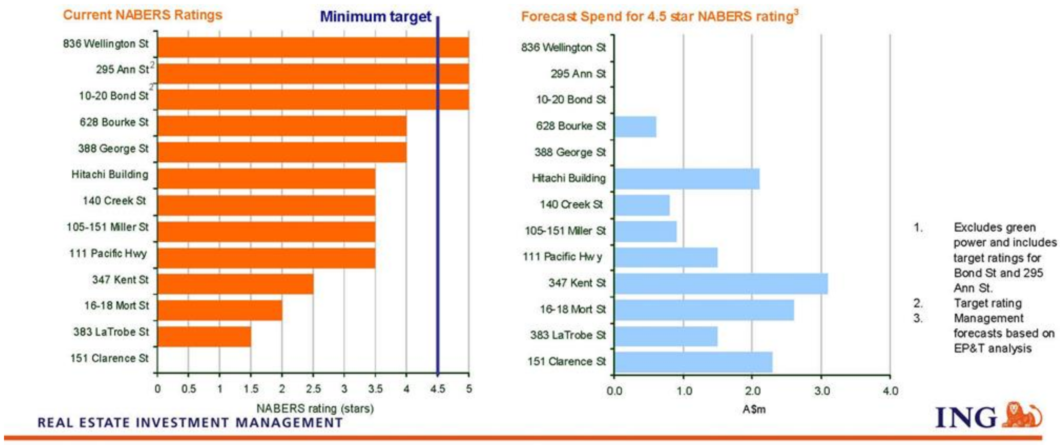

Figure P.1. For the ING Office Fund, planned investment is inversely related to current NABERS Energy ratings. Source: Investa (2011)

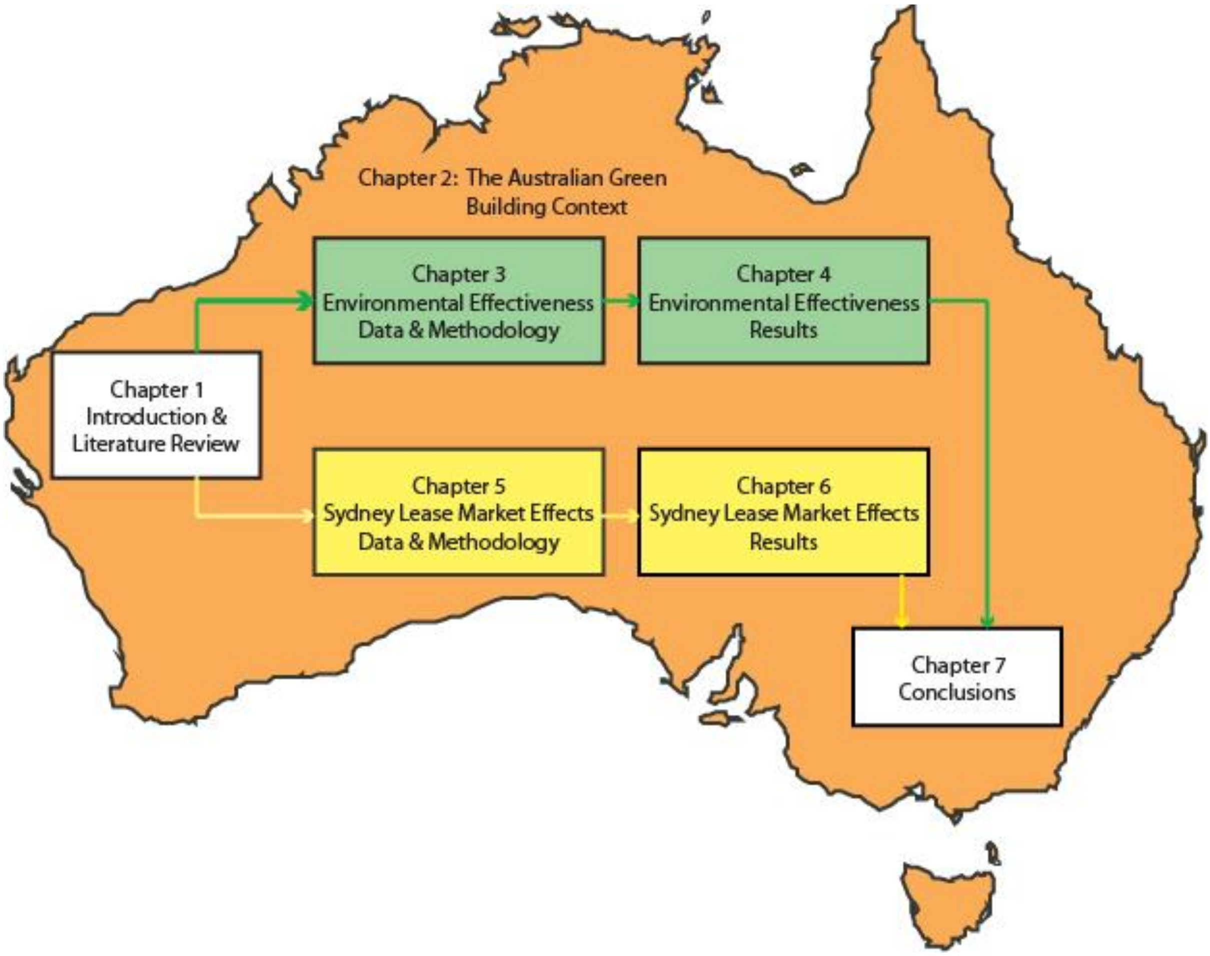

Figure P.2. Outline of this thesis.

Major contributions to the property literature from this study are four-fold. First, this study empirically tests the outcome of a market differentiation strategy – repeat energy consumption auditing using NABERS Energy – designed to improve energy efficiency and mitigate greenhouse gas emissions in existing commercial office assets. As will be discussed in Section 1.1.2, the literature on systematic resource efficiency outcomes from environmental market differentiation is surprisingly sparse, consisting of a few studies on the energy performance of new office assets designed to be efficient. Given the long serviceable life of office assets, rapid transitions to resource efficiency will require the renovation of existing assets. Chapter 3 describes how the author collates raw primary data, over 3,500 NABERS Energy certificates (nearly every certificate ever issued in Australia), into a database that enables a test of whether repeat certification affects asset energy performance outcomes. Chapter 4 finds that the NABERS Energy scheme has indeed been successful at motivating private investment in operational energy efficiency, with a strong positive relationship between depth of participation (number of re-certifications) and asset energy efficiency.

Second, this study is the first to examine differences in energy efficiency outcomes as a function of the motivation for entering an energy disclosure scheme. Public policymakers are interested in property market interventions that reduce greenhouse gases and improve the natural environment. One of these interventions is mandatory energy performance disclosure, which was implemented in Australia starting in late 2011. Chapter 4 finds early evidence from the NABERS Energy dataset to suggest that resource efficiency outcomes from mandatory disclosure are statistically similar to outcomes under voluntary disclosure. If anything, mandatory adopters of NABERS Energy in Australia reduce energy consumption – and greenhouse gas emissions associated with this consumption – faster than voluntary adopters because the latter group has developed a market for existing building energy retrofits.

The third contribution is an improved empirical understanding of the effects of asset energy efficiency differentiation on the office leasing market. Unlike the scarcity of studies on the resource consumption effects of green building certification, market effects have been studied in much greater depth. Section 1.2.2 finds studies from the United States, Australia, and Europe reaching a consensus view that energy efficiency and rental income are positively associated; the most energy efficient assets attract the highest rents if all else is equal. But the question regarding tenant willingness to pay higher rents has not been adequately tested because these existing studies take an owner's viewpoint from the asset scale. Instead, like Brian Churchill's expectations on the investment strategy of Local Government Super discussed earlier, tenant willingness to pay higher rents for energy efficiency remains a largely anecdotal expectation. Chapter 5 discusses how the author produced a lease transaction database directly from registered lease contracts in Sydney, Australia's largest and most competitive commercial office market, in order to model the relationship between energy consumption and rental price using multivariate regression techniques. Chapter 6 estimates these models and finds that tenants in the Sydney office market as a whole do not alter their rent bids as a function of asset energy consumption. Increased rental income per tenant does not appear to be a general outcome of investments in asset energy efficiency.

The fourth major contribution is theoretical support for the lack of increased rental income per tenant. The literature discussed in Section 1.2.2 expects tenants to pay higher rent for energy efficiency, but this study finds it is based on an incomplete analysis of tenant factor costs. In Chapter 6, an analysis of the Sydney office market from the tenant viewpoint finds that financial and legal motivations to pay a premium are absent, leaving corporate social responsibility (CSR) and other subjective benefits, such as Churchill's assumption that tenant productivity in Local Government Super assets would increase by nearly 200% of his firm's investment, as the only reason for tenants to increase rent bids in energy efficient accommodation. A confirmation of this theoretical revision is provided in the appendices, where it is shown that if the sample of lease transactions is restricted to only prime assets, wealthy tenants reveal a weak signal of willingness to pay for energy efficient accommodation, in line with literature suggesting that CSR benefits are more likely to be in demand from wealthy firms (McWilliams and Siegel, 2001).

These contributions are designed to influence property theory, policy and practice. Chapter 7 discusses five potential applications. The first is an implementation framework for policymakers interested in the use of performance disclosure to mitigate greenhouse gas emissions. Second, the findings of tenant indifference to asset energy efficiency in Sydney imply that split incentives are not as significant of a barrier to private investment in asset energy efficiency as the literature assumes. The next two applications improve strategic property investment using energy efficiency; asset repositioning is a necessary context for this investment and risk is increased because returns are delivered via capital gains, not income. Finally, Australian property occupiers can trust their traditional market rent valuation methods as NABERS Energy ratings do not appear to be a determinant of rental rates.

Chapter 1

Introduction & Literature Review

This first chapter examines the real estate literature associated with natural resource efficient building, commonly referred to as "green building", starting at a large scale – what is green building – and working down to a more refined framework that identifies the research gaps to be filled with the contributions summarised in the Preface.

1.1 The Macro Context: Sustainability, Green Building and Energy

The concept of "green" or "sustainable" building has become commonplace in the study of real estate over the past decade. Eichholtz *et al.* (2013) document the rapid growth of "green building" as a term in the popular press alongside similarly rapid growth in attendance at an annual industry conference devoted to green building in the United States. The American Real Estate Society has a journal devoted to the topic, *The Journal of Sustainable Real Estate.* In that journal, Kontokosta (2011) has developed a database of over 200 regulatory policies designed to increase the development of green buildings. In addition, the concept of green building has become so popular in such a short time across the globe that Reed *et al.* (2011) argues in support of efforts to create harmonised standards from the heterogeneous assessment techniques of nearly 200 green building councils working in parallel. Stated preference studies often find that green building is perceived as an important future direction for the real estate industry (McGraw-Hill Construction, 2008).

So what is "green" or "sustainable" building? It is useful to place the former concept within the wider framework of the latter. Taking a general view, the popular concept of "sustainability" refers to the notion that human society, and therefore property markets, must be optimised for intergenerational efficiency as defined by the ability to provide non-declining economic utility forever (Neumayer, 2010). Any market failure that deviates away from non-declining rates of economic utility, however small, can be considered unsustainable. Sustainability thus includes an essentially endless scope of topics associated with perceived intergenerational market failures: social inequity, environmental pollution, public health barriers, and social injustice, to name a few. Hence, in this general form, sustainability is too vague to be useful in defining specific property market concerns, particularly given the multidisciplinary nature of real estate research.

"Green" is an adjective used for ideas that relate to the sustainability of the biophysical environment, ecosystem services and natural capital. The key concern is sustaining economic growth and prosperity once it is assumed that current growth or prosperity depends on the depletion of finite natural resources and disruption of ecosystems (Daly and Townsend, 1993, Meadows *et al.*, 2004). Embedded in this viewpoint is an argument that natural capital is economically non-substitutable (Neumayer, 2010). This means that natural capital can be converted into human and manufactured capital (such as labour, knowledge, or infrastructure), but human and manufactured capital cannot be converted into natural capital at practical rates or substitute for all natural capital. Markets, meanwhile, assume that all capital is substitutable (a dollar of forest products equals a dollar of human labour), leading to an unsustainable market failure[1]. Applying this general framework to the property sector, green building is thus defined as natural capital-efficient construction that reduces environmental damage when compared with construction methods that are simply price taking with no concern in regard to an effect on natural capital stocks[2].

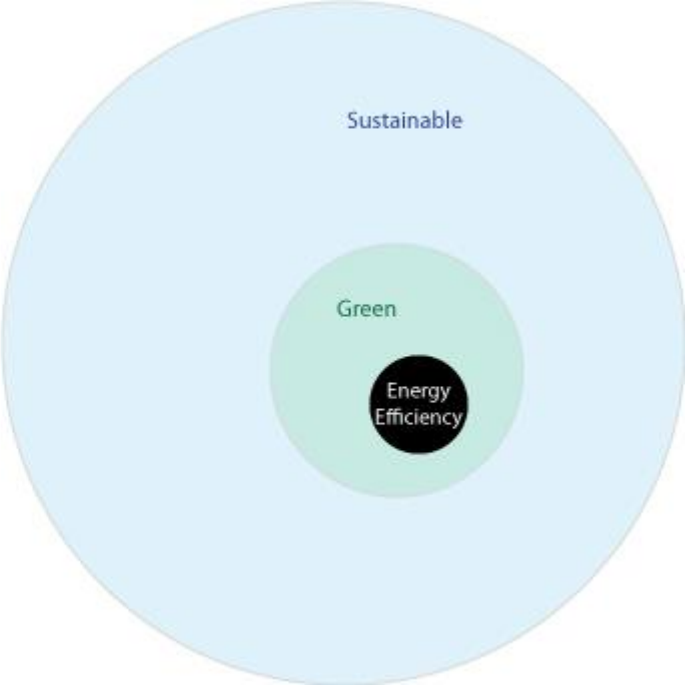

Figure 1.1. How energy efficiency fits within green and sustainable building.

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[1] This logic is the author's interpretation of popular discourse using the opposing paradigms described by Neumayer (2010) of "weak sustainability" (all capital is substitutable) and "strong sustainability" (some capital stocks are unique) as applied to the natural environment. The conceptual market failure is the market structure of weak sustainability while modern environmental problems are assumed to demand strong sustainability (see the discussion of greenhouse gas emissions later in this section for an example).

[2] It should be noted that the theoretical literature on green building (or green business practices) goes well beyond the basic framework discussed here. For example, if a second assumption is introduced that states the current level of natural capital is below some critical threshold (*i.e.* a maximum sustainable yield or measure of global carrying capacity), then green building must first become "restorative" or "regenerative" to enable the natural recovery of the critical non-substitutable stock (Hawken, 1993, Cunningham, 2002, McDonough and Braungart, 2002).

This framework of interaction between built and natural environments will be further narrowed for the purpose of this thesis. Natural capital takes many forms: water, energy supplies, materials, biodiversity, and the capacity to provide ecosystem services, for example. Some contexts of green building in the property literature, such as holistic green building assessment tools exemplified by LEED [Leadership in Energy and Environmental Design] and Green Star, consider as many of these natural capital domains as possible (Cole, 1999). But the contributions of this study will only consider the role of energy in green building. Figure 1.1 visually depicts the narrow scope of this study and how energy concerns are a subset of green building, which is itself a topic concerned with sustainability.

Energy consumption is important to the property industry for two reasons. First, the consumption of energy is associated with greenhouse gas pollution that causes anthropogenic global warming. The United Nations Environment Programme (2007) estimates that buildings generate 30 to 40% of global greenhouse gas emissions. In Europe and other capital intensive regions, the United Nations finds that this percentage can be as high as 45%. Reviews of the economic implications of anthropogenic climate change conclude that global warming is the most critical market failure facing society (Stern, 2007, Tol, 2009, Stavins, 2011). As one of the largest consumers of natural resources and emitters of greenhouse gases, the building sector is often cited as an opportunity to improve natural resource efficiency and mitigate climate change (Pacala and Socolow, 2004, Levine *et al.*, 2007, Stern, 2007, De la Rue du Can and Price, 2008). As for the primary source of greenhouse gas emissions from the property sector, most research concludes that operational energy consumption is the dominant cause of greenhouse gas emissions[3] (Levine *et al.*, 2007).

The second reason energy consumption is important to the property industry is the risk of an energy price shock. Energy is a critical component of the global economy; numerous studies document the positive association between energy consumption and gross domestic product (Nel and Cooper, 2009, Brown *et al.*, 2011, International Monetary Fund, 2011, International Energy Agency, 2013). Fossil fuels, a non-renewable natural resource, account for approximately 80% of

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[3] The smaller sources examined in the Levine review are operational emissions from refrigerants and embodied emissions from the production of building materials. Left out of the review is the indirect effect that the property sector has on transport demand. Greenhouse gas accounting is an emerging field of study, though some accounting standards have been developed in light of the demand for corporate reporting (World Resources Institute and World Business Council for Sustainable Development, 2004). Following these standards, the Levine study largely conforms to emission liability accounting scopes one (direct emissions) and two (indirect emissions from electricity generation). Transport and embodied emissions both fall within the third scope – indirect emissions where other market participants have scope one liability. But in the case of embodied emissions, that scope one liability largely remains within the property and construction sectors (building material producers), while transport involves a much wider range of responsible parties such as vehicle manufacturers and individual behavioural choices.

global primary energy supply (International Energy Agency, 2013). As scarcity rents for this non-renewable resource increase, the property industry will need to adapt to the end of cheap energy (Heinberg and Fridley, 2010). As an example, between June 2009 and June 2010, nominal energy costs per square metre in central Sydney office accommodation increased nearly 20% for A-grade office buildings and over 35% for C-grade office buildings (Property Council of Australia, 2009, Property Council of Australia, 2010). The property sector's exposure to energy price shocks was studied by Jaffee *et al.* (2011), who produced evidence that forward energy price contracts in the United States have a strong positive association with the price of commercial property assets.

Improving asset energy efficiency will thus reduce the property sector's exposure to an energy price shock as well as mitigate greenhouse gas pollution. Towards this goal, the industry has made energy efficiency a key outcome within green building design and assessment (Newsham *et al.*, 2009). The remainder of this section discusses how the property industry integrates green building and energy efficiency into practice and reviews the literature on studies interested in the effect of these actions on measured improvements in energy efficiency.

1.1.1 Market Differentiation: The property industry's approach to green building

In response to global concerns regarding sustainability, the environment, and, more specifically, the energy issues discussed above, the property industry pursues a strategy of market differentiation to promote the development of green assets. This differentiation strategy relies on the use of green building assessment tools to identify market leaders. In addition, the industry has faced expanded regulation, such as the expansion of traditional building codes to include energy-efficiency design attributes (Jacobsen and Kotchen, 2013). But the practice of market differentiation via green building assessment tools defines the conversation in the property literature. As an indication of the growing importance of this market differentiation strategy, government actions have recently turned away from traditional regulation and towards unconventional policies that use differentiation as part of a market-based policy approach (Kontokosta, 2013).

The following two subsections describe the scope of green building assessment tools and their subsequent use by governments seeking greater market-based regulation. In the interest of keeping the discussion within the context of this thesis, the brief review will quickly narrow to concentrate on the role of energy efficiency within green building. Ding (2008) and Mitchell (2010) provide a more thorough history of voluntary green building assessment tools.

1.1.1.1 Green building and energy rating tools

Desire to differentiate green commercial office assets through the use of a third-party certification tool began over two decades ago. In 1990, the government-owned UK Building Research Establishment introduced BREEAM [Building Research Establishment Environmental Assessment Method] version 1/90 in the United Kingdom. As one of the creators of BREEAM, Prior (1993) described the growing public concern regarding damage to the global environment, poor indoor air quality and the need to raise awareness of the large contribution by the property sector to these problems as motivation for developing the certification scheme.

The scope of BREEAM version 1/90 set a precedent for the scope used to determine what constitutes a green building today. BREEAM was restricted to certifying new commercial office assets. Today, commercial office assets remain the primary market for green building certification although most other asset classes have since been included. As for the breadth of environmental concerns, BREEAM assesses an asset by the degree to which it exceeds contemporary regulatory standards in regard to “global-scale”, “neighbourhood-scale” and “internal environment” indicators when built. Global- and local-scale concerns include improving ecological health and mitigating ecological degradation – specifically deforestation, greenhouse gas emissions, and ozone depletion – while internal environment concerns included indoor air pollutants and their effect on human health[4] (Prior, 1993). Thus, energy efficiency in its role as a greenhouse gas mitigation strategy has been a component of the green building archetype from the beginning.

The assessment methodology of BREEAM is best described as a voluntary building code. Developers seeking certification are provided with a checklist of compliance standards and gain one credit for meeting each individual standard in a third-party audit of the building design. In BREEAM 1/90, the “greenness” – or depth of environmental quality – of the asset was based on the number of total credits awarded; more credits indicated a “greener” asset. Later revisions to BREEAM increased the number of standards and created easy-to-understand adjectives – “Certified”, “Good”, “Very Good”, “Excellent”, and “Outstanding” – that serve to communicate the degree of environmental quality based on the number of credits awarded.

The scope and methodology of BREEAM 1/90 has been used as a template for the development of similar certification tools across the globe. Reviews of the emergence of green building certification narrate the breadth and depth of global market penetration for voluntary building

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[4] While the research in this dissertation is predominantly concerned with the goal of improving biophysical environmental quality as opposed to improving human health, it is important to acknowledge that common understanding of green building as a holistic concept continues to include indoor air quality.

codes modelled on BREEAM (Cole, 2006, Ding, 2008, Sayce *et al.*, 2010, Reed *et al.*, 2011). In particular, the LEED [Leadership in Energy and Environmental Design] scheme developed in the United States and Green Star scheme in Australasia follow the model of BREEAM. The development and implementation of these voluntary building codes are managed by a “green building council”, which is best described as a private, usually non-profit, firm made up of representatives from the local construction and property industry. These green building councils provide a third-party audit of all certification applications that lends external credibility to these voluntary assessments.

Operational energy efficiency is one of the most important components of green building identification. For example, energy efficiency factors in nearly one-third of all LEED credit standards (Newsham *et al.*, 2009). However, the scope of assessment systems modelled on BREEAM is largely new construction[5]. This means that operational energy efficiency must be assessed through simulation. When energy performance is simulated, the result is typically referred to as an “asset rating” because it represents the potential performance of the asset. Potential performance is best defined as “assuming normal or default patterns of occupant behaviour and building operation, making it easier to distinguish between improvements in the physical features and improved efficiencies in use and operation” (Cole, 1999). The alternative is a “performance rating” representing measured *in-situ* performance, which is, of course, impossible to obtain pre-occupancy.

While market differentiation of new property developments began the discussion towards increased energy efficiency in the property sector, the speed of transition to an energy efficient future is sensitive to consumption in existing assets. Many existing assets pre-date the earliest forms of energy efficiency regulation in building codes. Building stock replacement rates in developed countries range between 0.66% to 3% per year (United Nations Environment Programme, 2007, Holness, 2008, Jowsey and Grant, 2009, Eichholtz *et al.*, 2010), meaning that a complete transition to current building code performance standards could take somewhere between 30 and 130 years[6]. Unsurprisingly, forecasts of future energy consumption for an entire asset stock conclude that existing assets have a disproportionate effect on total consumption (Coffey *et al.*, 2009, Seo and Foliente, 2011).

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[5] “Major” renovations are allowed to apply for certification as a new building. The responsible green building council defines what constitutes a major renovation.

[6] This statement refers to the performance standards of current statutory building codes. A change to the high-performance expectations of most voluntary green building codes would take much longer. Kok *et al.* (2012b) estimate that only 10% of new construction in the United States has sought certification under the LEED assessment system.

In light of the importance of existing assets, the framework of market differentiation has gradually expanded so existing assets can participate. Early approaches to green differentiation for existing assets were based on the disclosure of energy consumption indicators. Although measuring *in-situ* energy consumption is possible in existing assets, both asset and performance ratings are used to measure energy consumption. The European Union Directive 2002/91/EC mandating energy rating disclosure in the sale or lease of any real property asset is one example of a performance disclosure system using simulated asset ratings: in order to eliminate the effect of behaviour, the energy needed to heat or cool an asset to a benchmark temperature is simulated. Examples of assessment systems using performance ratings include Australia's NABERS [National Australian Built Environment Rating System] Energy or the United States Energy Star labelling scheme, both of which are based on an annual audit of energy consumption.

Recently, the presence of multi-indicator assessment typical of voluntary green building code tools has emerged to complement the existence of single-indicator ratings. For example, the administrators of BREEAM now have a "BREEAM In Use" tool while the United States Green Building Council produced "LEED for Existing Buildings: Operations and Maintenance". Energy consumption within these holistic rating tools for existing assets is typically based on the single-indicator assessment systems described above[7].

Table 1.1 provides a brief comparison of how performance ratings and asset ratings are used to represent energy performance in green building assessment. The key difference is the methodological objective, as explained above: performance ratings measure audited *in-situ* performance while asset ratings estimate a measure of potential performance. Another notable difference is the validity period of issued certificates. Performance ratings are reviewed frequently while asset ratings are not. The reason for this is that potential performance only changes in the event of a major physical renovation while actual performance can vary from year to year based on user behaviour and other exogenous influences such as weather conditions.

Note that Table 1.1 is not meant to be a comprehensive survey of global property sector approaches to energy assessment. It is, however, a reasonable outline of the methods used when certification for the purpose of differentiation was first developed. As such, these methodologies lie behind the empirical literature on the property market effects of green building assessment.

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[7] For example, the methodology behind Energy Star is used for the energy efficiency credits in LEED for Existing Buildings: Operations and Maintenance.

Table 1.1. Two distinctive methods of representing energy consumption in green building certification.

	Asset Rating	**Performance Rating**
Objective	Communicate potential performance	Communicate measured performance
Example Systems	BREEAM New Construction (UK) LEED-New Construction (North America) Green Star Design/As-Built (Australasia) Energy Performance Certificates (Europe)	Energy Star (United States) NABERS (Australia) LEED Operations and Maintenance (O&M)
Market	All buildings	Existing buildings in-use at least one year
Certificate Validity	Long-term [10 years (EPC) to life of the asset (LEED)]	Short-term [1 year (NABERS) to 5 years (LEED O&M)]

1.1.1.2 Market-based Policy

The success of market differentiation to define popular discourse on energy efficiency in the property sector can best be demonstrated by the subsequent use of the assessment tools described above in public policy. For example, Kontokosta (2011) finds that many municipal governments in the United States have mandated a LEED threshold for the development of new public buildings. Some of these municipalities, such as the City of San Francisco, extend the LEED mandate to cover private commercial building developments[8].

As this example demonstrates, public policymakers are well positioned to intervene in regard to the energy efficiency of new buildings. However, public policy aimed at intervening in the energy efficiency of existing assets has less precedent. With the exception of major redevelopment activities, existing assets are not typically subject to post-construction revisions of building codes. Thus, governments must enact new policies if it wishes to intervene in the energy consumption of existing buildings. Energy disclosure schemes have opened up the intervention of mandatory disclosure (Kontokosta, 2013).

Mandatory disclosure is an indirect “market-based policy” in that it relies on the market to price energy efficiency, or any other indicator, creating an incentive for private investment (see Section 1.2 for literature reviewing the incentive mechanism). There is an emerging literature arguing that a market-based policy approach is preferred because traditional top-down regulation, while effective, is costly, rigid, inefficient, and adversarial (Borck and Coglianese, 2009). In an archetypical market-based policy, governments do not set a statutory minimum performance threshold, so the outcome of mandatory disclosure is largely unknown and relies on expectations

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[8] Property law literature questions the wisdom of mandating a voluntary building code developed by a private firm, but not the overall intention of the policy. As an example, Schindler (2010) argues that the LEED mandates described by Kontokosta (2011) circumvent democratic process and grant the US Green Building Council significant power over the issuance of building permits without the oversight of elected officials. Schindler suggests that simply revising local building codes would be a more appropriate public policy approach given the similarity between conventional building codes and green building certification.

that consumers will prefer energy efficiency if the market is adequately differentiated. Gabe and Gentry (2013) discuss the theory behind market-based policy in more detail.

In-line with the development of energy disclosure schemes, early attempts at market-based policy mandated asset ratings for existing buildings. The Australian Capital Territory (ACT) was first to experiment with mandatory disclosure of energy consumption potential in the built environment. Since 1999, sales advertisements for detached residential houses are required to display an Energy Efficiency Rating (EER) that simulates the cost of energy used to heat and cool the dwelling in a typical year (Soriano, 2008). Closely resembling the ACT regulation, European Union (EU) Directive 2002/91/EC mandated that all member states make an Energy Performance Certificate (EPC) available to interested parties during the sale or lease of commercial and residential property. The European directive relaxes the ACT restriction on building type, but in practice, EU states implemented the directive in stages starting with detached residential and gradually expanding into different commercial property sectors. Each member state of the EU also has wide latitude to define the methodology of producing an EPC. Despite the word performance in the title, an EPC is an asset rating simulating annual heating and cooling energy required in a typical year, just like the ACT EER.

More recent attempts at mandatory disclosure policies use performance ratings. In 2010, the Building Energy Efficiency Disclosure (BEED) Act in Australia mandated that, at lease or sale, large commercial office assets must disclose a NABERS Energy certificate conspicuously in advertising materials (see Section 2.2.3). Similar performance rating disclosure laws have been enacted at the local and state level in the United States using the Energy Star methodology. California passed mandatory performance disclosure law Assembly Bill 1103 in 2007, though its implementation was delayed until 2013. The California mandatory disclosure scheme is nearly identical to BEED – restricted to office property transactions involving large buildings. Kontokosta (2013) discusses the plan for mandatory performance disclosure in New York City.

In summary, private initiatives to create market differentiation within the property industry in regard to green building and asset energy efficiency are seen as a potential strategy for public policymakers seeking to mitigate greenhouse gas pollution. With the macro framework in Section 1.1 describing the objective behind green building as a desire to fix intergenerational market failures associated with the biophysical environment, this market-based policy approach would appear to be an appropriate response. However, the outcome of market-based policy is reliant on an assumption that markets will value energy efficiency and other environmental attributes. This discussion continues by reviewing the literature measuring the environmental outcomes of market differentiation.

1.1.2 The Effect of Market Differentiation on Asset Energy Efficiency

Why is market differentiation expected to increase the energy efficiency of the built environment? In a paper on the general practice of using ratings to segment markets, Chatterji and Toffel (2010) argues that firms will adapt their practices in order to improve external ratings, particularly if the market perceives them to be rated poorly. Fuerst and McAllister (2011b) and Kontokosta (2013, p.35) apply this general theory of behaviour change through differentiation to the property sector, with the latter arguing that, "the potential for energy disclosure policies to shift market awareness of building energy efficiency is substantial". Later, Section 1.2 reviews the scope and mechanism of market transformation through differentiation as it applies to the property sector in more detail. This section looks at literature assessing the outcome of market differentiation in regard to its effect on the environment.

The use of certification to differentiate products based on environmental credentials is not unique to the property sector. Borck and Coglianese (2009) review the general environmental management literature on market differentiation and produce a helpful framework to understand the environmental outcome of differentiation as a market intervention. The environmental effectiveness of market differentiation[9] is assessed as follows:

$$Effectiveness = \begin{matrix} Number\ of \\ Participants \end{matrix} \times \begin{matrix} Effect \\ per\ Participant \end{matrix} + \begin{matrix} Spillover \\ Effect \end{matrix} \qquad (1.1)$$

where "effect per participant" measures the average environmental performance outcome for the market segment that enters the voluntary scheme. For energy efficiency, effect per participant can be measured by the quantity of energy saved as a result of participating in a voluntary disclosure scheme. The "spillover effect" represents the influence of participants on the behaviour of non-participants, such as the development of new energy efficient technologies that may diffuse throughout the entire property sector.

Using this framework, the property literature implicitly assumes that effect per participant, including energy efficiency, is non-zero given participation in a robust certification process (for

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[9] Throughout this dissertation, the author's intent is to define environmental effectiveness narrowly as the production of energy efficiency and, by extension, mitigation of greenhouse gas emissions. However, the literature often takes a broader approach, assuming that participation in a holistic green building assessment tool such as LEED delivers a bundle of environmental benefits, not just energy efficiency. In this section, environmental effectiveness is used loosely to match the scope of the literature. Chapters 3 and 4 adopt the narrower definition associated with energy efficiency.

example, Miller *et al.*, 2008, Eichholtz *et al.*, 2010, Fuerst and McAllister, 2011b). The implication is that the participation rate plus difficult to quantify spillover effects determine the outcome of voluntary certification. Hence Fuerst (2009) and Eichholtz *et al.* (2013) attribute increasing participation in voluntary green building assessments as evidence of their effectiveness in mitigating energy-related greenhouse gas emissions emitted by the property sector.

Kok *et al.* (2012a) model the drivers of participation in voluntary green building assessments. They address this within a framework of an “energy paradox”, wherein the adoption of energy efficiency technologies in commercial office assets is observed to be much less than these authors’ expectation regarding the profitability of investment in these technologies. Their model finds adoption rates of LEED certification vary by metropolitan area and argue that higher incomes and indicators of a “healthy” competitive property market (i.e. low vacancy rates and high capital values) are positively associated with the spatial adoption of energy efficient technologies. Kok *et al.* also argue that differences in energy prices influence the diffusion of assets certified as energy efficient.

In a similar study, Fuerst *et al.* (forthcoming) model variations in the diffusion of LEED-certified assets across metropolitan areas of the United States. They argue that LEED certification behaves as a “luxury good”, in that green assets are more likely to be developed and purchased by wealthy consumers. Their model thus concurs with the Kok *et al.* model in that green assets are most likely to be found in affluent markets with a highly educated population. The Fuerst *et al.* model also addresses the impact of policies promoting (not mandating) LEED certification on the distribution of assets, finding limited empirical support of a positive association between policy and the adoption of LEED certification.

Both of these studies agree that voluntary participation in green property market differentiation appears to be strongest in wealthy markets, leading to the conclusion that energy efficiency and other green performance attributes are luxury goods. However, placing this framework within the model of environmental effectiveness (Equation 1.1) is only useful if effect per participant is not zero. But another body of literature, reviewed below, argues that effect per participant in green building assessments on energy efficiency outcomes may be zero.

The mechanism that leads to the possibility of diminished effect per participant is the use of asset ratings, which simulate potential performance, not measured outcomes. Asset ratings are preferred by architects, engineers, and consultants in the property development sector because their objective is to isolate the effect of decisions made in design by excluding variation caused by human factors in building operation and management. Unsurprisingly, there are many detailed case studies of individual assets that underperform their potential for energy efficiency (for examples, see Bordass *et al.*, 2001, Scofield, 2002, Gabe, 2008).

But is underperformance systematic? Two studies of LEED-certified assets argue that, while variance at the individual asset level is high, certified green buildings are more energy efficient than comparable uncertified assets on average (Turner and Frankel, 2008, Fowler *et al.*, 2011). Data on energy consumption from the Turner and Frankel study has been subjected to an additional two statistical analyses, one of which confirms the original conclusion (Newsham *et al.*, 2009) while the other finds evidence of systematic underperformance in large assets (Scofield, 2009).

A third empirical study in the United States also found evidence of systematic underperformance. Oates and Sullivan (2012) studied 19 office assets in Arizona, finding that 18 underperformed relative to the asset rating and 15 underperformed the baseline building code specification for energy efficiency. These authors note that a small sample size and unique arid climate creates difficulty when extrapolating this result to a wider asset population.

Surprisingly, these three studies are the only empirical investigations into the systematic effect of green building certifications on asset energy consumption. Data availability is one reason for this lack of research. One of the studies reports that very few green assets measure asset energy consumption post-occupancy (Oates and Sullivan, 2012). In addition, the three studies obtaining in-use performance data to assess the effect of LEED were forced to rely on self-selected surveys of asset managers. With asset owners choosing whether to measure *in-situ* performance and, if so, also choosing whether to disclose that performance, these three studies are vulnerable to sampling bias. With such noisy results and small samples, it is difficult to assess the impact of sampling bias in these studies.

Another problem is the lack of an appropriate benchmark in the non-certified population for comparison. Newsham *et al.* (2009) uses a five-year old survey of commercial asset energy consumption across the United States to statistically extract the most comparable non-certified asset for each LEED asset in the Turner and Frankel (2008) dataset. Both Turner and Frankel (2008) and Oates and Sullivan (2012) attempt to compare a simulated asset rating with post-occupancy measured performance, but discuss how asset ratings are not meant to measure total consumption. Asset ratings ignore behavioural energy demand, such as plug loads (computers and other equipment that receives power from a wall socket), so a researcher receiving total energy consumption data post-occupancy must estimate how much of that energy is consumed by the services included in an asset rating. This introduces the potential for significant error in addition to any effects from sampling bias.

Researchers have begun to address the lack of benchmark data via two alternative methods. One approach is similar to the survey used by Turner and Frankel and seeks to collect raw data on performance from representative samples of all existing buildings. For example, a large project in the European Union is attempting to track each member nation's commercial asset energy consumption over time (Buildings Performance Institute Europe, 2011). Alternatively, a separate approach simulates the entire building stock. Seo and Foliente (2011) model the entire commercial office sector in New South Wales, providing a benchmark of total greenhouse gas emissions and a forecast of implications resulting from various policy alternatives. Future empirical data can then be compared with these forecasts.

The last factor in the model of environmental effectiveness from voluntary interventions is the spillover effect term. As Borck and Coglianese (2009) report in their review, little is known about the existence or size of spillover effects. In the property sector, Simcoe and Toffel (2013) find evidence of a spillover effect resulting from government procurement policies that have led private building producers to adopt LEED construction standards as a *de facto* construction standard for non-government projects. However, their conclusion comes with caveats typical of studies looking for spillover effects, namely the possibility of reverse causation (i.e. environmentally conscious municipalities are the ones likely to develop green procurement policies). Another example of spillover effects is the use of methods developed in voluntary rating tools to draft statutory building code revisions (Simons *et al.*, 2009, Kontokosta, 2011).

1.1.3 First Research Gap: Measuring Effect per Participant in Existing Assets

The discussion above noted that little is known regarding the energy consumption outcomes per participant in green market differentiation schemes for new commercial office assets. Even less is known about energy consumption outcomes of interventions in existing assets. No studies have investigated measured energy consumption outcomes per participant as a result of participation in energy disclosure schemes. In the case of existing assets, the comparison is not between potential and actual performance, but whether repetitive participation in disclosure schemes influences investment in environmental improvement.

Chapters 3 and 4 in this thesis will fill this gap and contribute to understanding the environmental effectiveness of existing office asset disclosure schemes. With the introduction of energy performance ratings in Australia through the NABERS Energy scheme in 1999 (see Chapter 2), over 800 assets have been certified multiple times, creating an appropriate benchmark – prior consumption measured in the same asset – for calculating effects from participation. Chapter 3 discusses the compilation of over 3,000 NABERS Energy disclosures and specifies a set of univariate and multivariate models to assess energy efficiency outcomes as a function of depth of participation in the disclosure scheme (measured by the number of certificates per asset).

One expects that asset managers will use repetitive auditing of energy performance to reduce consumption. This is in line with the theory developed in Chatterji and Toffel (2010) and Kontokosta (2013). As this chapter will outline in more detail later (Section 1.2), the theme of early green building literature is an expectation that tenant consumers prefer lower resource consumption if all else is equal, thereby creating a market for resource efficiency (Sayce *et al.*, 2010, Warren-Myers, 2012). Hence the empirical models in Chapter 3 will test whether owners and developers manage energy efficiency in response to the creation of a market for it.

1.1.4 Second Research Gap: Does Motivation Affect Energy Performance Outcomes?

Kontokosta (2013) argues that mandatory performance disclosure is important to the institutionalisation of energy efficiency within the real estate profession. However, an assumption that mandatory adopters will behave similar to voluntary adopters underlies his theory behind the attractiveness of mandatory disclosure and other market-based policies that rely on differentiation to improve environmental quality in lieu of traditional regulation through performance standards.

But is this assumption valid? No research has addressed this question empirically, so this thesis will be the first to compare post-certification performance between voluntary and mandatory adopters of an energy disclosure scheme designed to differentiate energy consumption in commercial office markets. Under the BEED Act, the use of NABERS Energy has been mandatory for large commercial property lease and sale transactions in Australia since late 2011, so the database constructed in Chapter 3 contains a mix of mandatory and voluntary adopters.

Theory suggests that only building owners standing to gain market share with resource efficient buildings will voluntary disclose their asset position in regard to energy efficiency (Borck and Coglianese, 2009, King and Toffel, 2009). Owners forced to commence NABERS Energy certification via mandatory disclosure are likely to be disinterested in energy efficiency as an asset positioning strategy and, given their implicit success in business outside of the voluntary disclosure regime, less likely to see value in operational energy efficiency investment. The question facing these owners is whether perceived costs of disclosing poor energy ratings exceed the value in continuing business as usual.

The environmental benefit of a mandatory disclosure policy is best assessed relative to the benefits attainable through any pre-existing voluntary arrangement. In this context, mandatory disclosure policies are designed to influence participation rates, raising them closer to 100%[10]. Returning to the Borck and Coglianese (2009) framework (Equation 1.1), spillover effects are zero if participation is mandatory (at least within the market subject to mandatory disclosure). Hence effectiveness of mandatory disclosure is determined by the average effect per asset:

$$\begin{matrix} Effect\ of \\ Mandatory\ Disclosure\ (MD) \end{matrix} = Asset\ Population \times \begin{matrix} Average\ Effect \\ per\ Asset\ (post\ MD) \end{matrix} \qquad (1.2)$$

Subtracting Equation 1.1 from 1.2, the change in environmental effectiveness as a result of mandatory disclosure converting non-participants into participants can be expressed as:

$$\Delta Effectiveness = \begin{matrix} Number\ of \\ Mandatory\ Adopters \end{matrix} \times \left(\begin{matrix} Average\ Effect\ per \\ Mandatory\ Adopter \end{matrix} - \begin{matrix} Spillover \\ Effect \end{matrix} \right) \qquad (1.3)$$

Thus, the critical relationship is between average effect per mandatory adopter and the spillover effect. If mandatory adopters are disinterested in the benefits of differentiation based on energy efficiency, then their participation outcome will equal the spillover effect[11].

Comparing the average effect per mandatory adopter and the average effect per voluntary adopter is the best proxy for estimating the change in environmental effectiveness created by the introduction of a mandatory disclosure policy. The review above found the spillover effect very difficult to measure because of its subjective nature (Borck and Coglianese, 2009). If the effect per mandatory adopter is significantly less than the effect per voluntary adopter, then it becomes debatable whether the mandatory disclosure policy in question is mitigating greenhouse gas emissions from the commercial office sector more than the pre-existing combination of voluntary reductions and associated spillover effects.

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[10] Participation rates only reach 100% in the specified market segment. In Australia, mandatory disclosure only applies to large assets occupied for at least two years during the sale or lease of office space greater than 2,000 m^2 under corporate ownership. If this narrow definition of the market is assumed, then participation rates should be 100%. For the population as a whole, mandatory disclosure is expected to significantly increase participation rates.

[11] According to this model, a mandatory disclosure policy could theoretically result in a negative value for change in effectiveness if the effect per mandatory adopter is less than the spillover effect. However, this scenario would require evidence of an active effort on the part of mandatory adopters to resist the passive benefits that define the subjective spillover effect.

As part of the investigation into the effects of NABERS Energy certification, Chapter 3 develops models of energy savings per asset at a fixed depth of participation in the disclosure scheme. Definitions of mandatory adopter are developed and used in the model to control for the motivation to participate. Chapter 4 discusses the estimation of the mandatory adopter variables and the implications in regard to expectations for mandatory disclosure policies being considered in other markets.

The remainder of this chapter pivots to discuss why the property sector expects asset owners to reduce energy consumption as a response to the presence of market differentiation. Green building rating schemes are designed to affect the valuation of property as a means to mitigate greenhouse gas emissions.

1.2 The Micro Context: Market Effects

Having established a broad framework of how asset energy efficiency fits within a wider green building movement and an even wider sustainability movement, this section describes the theoretical models of how asset energy efficiency and market differentiation impact the property market. Two mechanisms are common in the literature discussed in this section. First, a property valuation perspective assesses how asset energy efficiency affects traditional measures of asset value. The second approach addresses the creation of more subjective benefits that do not fit within these traditional measures of value, such as the marketing and perception benefits associated with credible signals of corporate social responsibility (CSR).

Corbett and Muthulingam (2007) use the terminology of “intrinsic benefits” to describe the first pathway and “market signalling” to describe the second. To illustrate the difference, consider Energy Star certification in the United States, one the simplest forms of identifying an energy efficient asset. An office building is certified under Energy Star if its annual energy consumption falls in the bottom quartile of a national sample of office buildings, meaning it uses less energy than at least 75% of comparable assets. Owners and tenants in an Energy Star-certified building can be assumed to face lower energy costs than a competitor in a non-certified building, since the certification is directly based on measured performance. These lower costs are intrinsic benefits that result from the action required for certification. In addition, a tenant may try to market its services as environmentally responsible, citing the lease of Energy Star-certified office space as an example of its commitment. In this case, the credible market signal of third-party certification is the source of value. Of course, the two value pathways are not mutually exclusive; owners and tenants can benefit from both intrinsic benefits and market signalling.

1.2.1 How Green Building Affects Property Valuation

In property valuation theory, the value of an asset to its owner is the net present value of all future income (R) minus any non-recoverable operating expenses (E), represented by the model in Equation 1.4, where g_R and g_E are the expected growth rate in rental income and operating expenses, respectively, and i is the owner's desired rate of return on capital for a given level or risk:

$$Asset\ Value = \sum_{t=0}^{T} \frac{R_0(1+g_R)^t - E_0(1+g_E)^t}{(1+i)^t} \tag{1.4}$$

Since the prediction of future cash flows and expenses is uncertain and subjects this model to forecasting bias, a reduced model of property value based on present-day net operating income is often used in practice (Fuerst and McAllister, 2011a). In this reduced model, represented by Equation 1.5, the asset value is assumed to be equivalent to the purchase of a financial perpetuity. Periodic income to the owner is represented by present net operating income (NOI), which is rental income minus non-recoverable expenses. Property value is estimated by dividing NOI by the capitalisation rate (r_c; often abbreviated in prose as the "cap rate"), which represents the owner's required rate of return based on his risk assessment minus the expected rate of growth in NOI (g):

$$Asset\ Value = \frac{R_0 - E_0}{i - g} = \frac{NOI}{r_c} \tag{1.5}$$

From this reduced model, it is possible to hypothesise how asset energy efficiency raises market value. In the numerator, NOI can increase because tenants may be willing to pay a premium for rent or owners are faced with fewer expenses. In the denominator, the cap rate could decrease if the investor perceives less risk associated with the income stream or if the income stream is expected to grow faster.

An extensive body of valuation literature concludes that green assets deliver a bundle of intrinsic and market signalling benefits to both tenants and owners, with the net result of increased asset value using the models above. Lorenz and Lützkendorf (2008), Sayce *et al.* (2010) and Warren-Myers (2012) have reviewed this literature extensively. From these reviews, Table 1.2 summarises the sources of these benefits and which party is the beneficiary. As expected, intrinsic benefits to owners can manifest through increasing NOI or reducing the cap rate. As a measure of reduced risk, lower cap rates indicate willingness of an owner to accept low income returns relative to the asset's capital value. Both increased NOI and lower cap rates will lead to increased asset value as explained above.

To integrate market signalling into the valuation equation, it is necessary to add an additional term, *MS Value*, representing the bundle of benefits from market signalling, into Equation 1.5:

$$Asset\ Value_j = \frac{NOI}{r_c} + MS\ Value_j \tag{1.6}$$

The subscript, *j*, is added because the exercise of calculating market signalling value expands the scope of property valuation into business, or firm, valuation. This also expands the body of relevant literature into the area of corporate social responsibility (CSR) within the study of management. Pivo and McNamara (2005) review this disciplinary interaction between property and management, referring to the practice of CSR by professional property investors as "responsible property investment".

Many of the insights in the CSR literature are applicable to responsible property investment. In particular, McWilliams and Siegel (2001) conclude that CSR benefits are contextual and depend on the competitive environment surrounding any particular firm. One of these contexts relates to a positive association between firm wealth and CSR benefits; wealthy firms benefit most from market signalling. In line with this theory, Fuerst *et al.* (forthcoming) find evidence that wealthy property markets are the most likely to adopt green building practices.

Table 1.2. Theoretical benefits of green building practices on asset value. Sources: Lorenz and Lutzkendorf (2008) and Warren-Myers (2012). The author of this thesis divides the theoretical benefits into intrinsic and market signalling categories.

	Tenants	**Owners/Developers**
Intrinsic Benefits	Reduced operating costs Improved labour productivity Reduced environmental footprint	Higher NOI Reduced vacancy costs Less tenant churn Shorter search time to fill vacancies Increased rental income per tenant Reduced operating costs Reduced maintenance costs Reduced financial risk Mitigate future regulatory impacts Lower obsolescence/vacancy risk
Market Signalling Benefits	Enhanced brand/reputation Retention/attraction of skilled labour Efficient CSR reporting to stakeholders	Enhanced brand/reputation Market differentiation (asset positioning) Marketing benefits Efficient CSR reporting to stakeholders Inclusion in sustainable property indices Access to targeted tax relief and subsidies

The best evidence that market signalling is an important part of green building valuation is the presence of "greenwashing", or fraudulent attempts to obtain a green reputation without pursuing resource efficiency (Delmas and Burbano, 2011). If green property valuation benefits were solely based on intrinsic benefits, greenwashing would be an ineffectual strategy because intrinsic benefits result from the underlying efficiency gains. Fuerst and McAllister (2011b) discuss an example of greenwashing in the United States where an owner was cited for fraudulently advertising green building certification credentials.

Lorenz and Lützkendorf (2008) advocate the position that it is the job of property valuation professionals to integrate market signalling benefits into the property industry. When property investment firms are the targeted business for estimating signalling benefits, this is not very far outside the expertise of property valuation professionals. But for more diverse asset owners or prospective owner-occupiers from other economic sectors, this exercise is likely to require collaboration between the business valuation and property valuation professions. Later work by Lützkendorf and Lorenz (2011) concentrates on a two-stage process in-line with Equation 1.6: (1) integrate intrinsic benefits into the traditional model of property valuation, and then (2) make a professional adjustment based on market-specific knowledge in regard to sustainability to account for the market signalling benefits.

There is debate regarding the generalised statement that responsible property investment has a positive association with asset value. Green price premiums may be market- and owner-specific, thus require a more strategic approach by property valuers and investors (de Francesco and Levy, 2008, Newell, 2008). Surveys of tenants find insufficient evidence to make a broad statement in regard to willingness to pay higher rent for green building accommodation (Miller and Buys, 2008, Galuppo and Tu, 2010). In addition, Robinson (2013) argues that green building procurement is highly correlated with other drivers of property value, particularly the presence of professional asset managers, making it difficult to extract the value of green attributes without advanced econometric techniques.

The cost of capital investment to obtain any green benefits is also a source of debate. On one side, a number of cost-benefit studies find no significant investment costs needed to generate the benefits described in Table 1.2 (Bordass, 2000, Kats *et al.*, 2003, Kats *et al.*, 2010, Rehm and Ade, 2013). But there are also studies finding that initial costs can be prohibitive, particularly when a firm lacks expertise associated with the production or management of green building attributes (Melaver and Mueller, 2009, Galuppo and Tu, 2010).

As the discussion above implies, the property valuation literature typically addresses the context of green building, as opposed to the more targeted subject of energy efficiency used in this thesis. This largely has to do with the popularity of holistic green building assessment tools and their role in framing the popular discussion on green building. However, it is worth re-examining Table 1.2 to consider adjustments based on the relationship between energy efficiency and property value.

In particular, there is little support in the literature for a direct relationship between tenant productivity and energy efficiency. The inclusion of indoor environment quality in the conventional understanding of green building has led to empirical studies linking indoor environments with human health and productivity indicators (Roulet *et al.*, 2006, Singh *et al.*, 2010). However, a relationship between indoor environment quality and operational energy efficiency is unclear. Fisk (2000) reviews the literature on this relationship and finds that short-term solutions to improve indoor environment quality are likely to *increase* energy consumption. There are limited contexts – on-site fossil fuel combustion, for example – where Fisk argues that it is theoretically possible to increase energy efficiency and improve indoor environment quality with the same investment.

If tenant productivity is removed from Table 1.2, it may have an effect on the relationship between green building and property value, though intrinsic benefits will still exist. For example, there is a natural relationship between energy efficiency and lower operational costs, so owners and tenants will continue to benefit financially from operational efficiency. Branding an asset as energy efficient has an implication that the asset owner has reduced greenhouse gas emissions and insured occupants against the full impact of potential energy cost inflation, so market signalling benefits are still attainable. However, the scale of financial rewards associated with labour productivity is large. Kats *et al.* (2003) finds that the operational benefits of improved tenant productivity are ten times the nominal value of energy efficiency. To better understand the relationship between asset energy efficiency and property value it is useful to examine a growing body of empirical literature on the topic.

1.2.2 Econometric Evidence: Asset Energy Efficiency and Office Property Value

Hedonic regression studies examining the market value of energy efficiency in office property find a range of value premiums for certified energy efficient buildings relative to uncertified buildings. Research in the United States finds evidence of rent premiums, occupancy rate premiums, cap rate reductions, and sales price premiums for Energy Star rated buildings (Miller *et al.*, 2008, Eichholtz *et al.*, 2010, Pivo and Fisher, 2010, Wiley *et al.*, 2010, Fuerst and McAllister, 2011a, Fuerst and McAllister, 2011b, Reichardt *et al.*, 2012, Eichholtz *et al.*, 2013). The rent and occupancy premiums from these models are summarised in Table 1.3. All studies find a positive association between Energy Star certification and indicators of asset value. In addition, all studies, with the lone exception of Pivo and Fisher (2010), use the same data source (CoStar), albeit with a sample drawn at different times. Pivo and Fisher use 10 years of data from the members of the National Council of Real Estate Investment Fiduciaries [NCREIF], a club consisting of major property investment managers in the United States.

Table 1.3. Asset-scale energy efficiency rent and occupancy rate premiums in United States market models for buildings obtaining Energy Star certification. Occupancy rate premiums are not investigated in all studies.

			Energy Star Premiums		
Study	**Time Period & Source**	**Adj. R^2**	**Rent**	**Occupancy Rate**	**Rent times Occupancy**
Eichholtz *et al.* (2010)	CoStar at Sept. 2007	0.69 (rents) 0.42 (rent × occ.)	3.3%[A]		10%
Eichholtz *et al.* (2013)	CoStar at Oct. 2009	0.82 (rents) 0.71 (rent x occ.)	2.1%[D]		6.5%
Fuerst and McAllister (2011b)	CoStar at Q4 2008	0.63	4%[A]		
Fuerst and McAllister (2011a)	CoStar at Q4 2009	0.60 (rents) 0.25 (occ. rate)	4%[A]	1 to 3%	
Wiley *et al.* (2010)	CoStar at Jan. 2008	0.62 (rents) 0.46 (occ. rate)	7.6 to 8.6%[A,F]	10 to 11% [F]	
Pivo and Fisher (2010)	NCREIF 1999-2008	0.48	2.7%[C]		
Reichardt *et al.* (2012)	CoStar 2000-2009	0.86 (rents) 0.71 (occ. rate)	2.5%[B,E]	4.5% [E]	

[A] Asking rent used to define rent

[B] Average gross rent used to define rent.

[C] Net operating income used to define rent

[D] "Contract rent" used to define rent at the asset scale. No further clarification on methodology given.

[E] Authors present a premium for each year (2004-2009) using difference-in-differences regression as well as a time-demeaned fixed effects regression for their entire dataset. Results from the fixed effects model are presented here.

[F] Class A buildings only.

Outside North America, studies on value premiums for energy efficient office space have been conducted in the United Kingdom (Fuerst and McAllister, 2011c, Chegut *et al.*, 2012, Fuerst *et al.*, 2013), the Netherlands (Kok and Jennen, 2012) and Australia (Newell *et al.*, 2011). These studies also concur on the positive association between energy efficiency and measures of asset value, but with two exceptions. Fuerst and McAllister (2011c) find no rent premiums and conjecture that their finding represents how difficult it is for prospective tenants to obtain an energy performance certificate in the UK. A later study on lease transactions by Fuerst *et al.* (2013) finds the rent premium for energy efficiency becomes inconsistent when asset age is interacted with the degree of energy efficiency, suggesting strong endogeneity between asset age and asset energy consumption in the sample.

These empirical studies all share a similar methodology. Following the hedonic price model popularised by Rosen (1974), the variable of interest (rent, sale price, or occupancy) is expressed as a bundle of unique characteristics. For example, using rent:

$$\ln(\text{Rent}) = \alpha + \sum_{i=1}^{n} \beta_i X_i + \gamma G + \varepsilon \tag{1.4}$$

where G is the unique characteristic of interest (usually a binary variable identifying a green or energy efficient asset), γ measures the contribution of G to the price of rent, $\sum_{i=1}^{n} \beta_i X_i$ represents a vector of n control characteristics X_i with β_i effect on rent, ε represents stochastic error, and α represents the baseline constant if all X_i and G equal zero. The hypothesis in a hedonic price model is that γ is not equal to zero. Ordinary least squares multivariate regression is used to estimate X_i, γ, and ε. A logarithmic transformation is typically applied to rent (or sale price) to convert it from a lognormal to a standard normal distribution.

Criticism of these econometric models as applied to green property premiums includes disputes over the appropriateness of control variables representing asset location. All the cross-sectional studies described above use a set of binary variables to represent asset location in the hedonic regression. Miller *et al.* (2008) uses metropolitan areas, with an additional variable isolating each metropolitan area's central business district. Eichholtz *et al.* (2010) finds metropolitan areas to be too broad and created a 0.2 mile radius to identify assets sharing the same fixed locational effects. Fuerst and McAllister (2011b) argue that the diversity of office markets in the United States mean this 0.2 mile radius is unlikely to create a proxy for actual submarkets. To correct for this, Fuerst and McAllister had sufficient data to use the submarket boundaries defined in the CoStar database, creating binary variables for over 800 defined submarkets. This high number of binary variables prompts Robinson (2013) to argue that Fuerst and McAllister's results are likely subject to the "incidental parameter problem", which is when a binary variable acts as an instrument for an unobserved characteristic. Instead of binary variables to control for location, Robinson argues that de-meaning each rent or sales observation by the mean of its submarket cluster prior to performing the regression (a "fixed effects" approach) produces more consistent estimators. The fixed effects approach leads to a smaller, and insignificant, effect from asset energy efficiency on sale prices and rental income in the United States (Robinson, 2013).

Another criticism with the American studies is that integration of markets across the entire country hides diversity in market responses to asset energy efficiency. Das and Wiley (2013) argue that green sale price premiums vary over time and between markets, hence combining multiple years and multiple markets masks these patterns. Robinson (2013) concurs and finds that the energy efficiency premiums found in all studies using CoStar data arise because energy efficiency premiums are strong in two of the most expensive office markets, New York City and San Jose. The fixed effects de-meaning process advocated by Robinson tempers the effect from these two markets' position on the far right-tail of the rent (or sale price) distribution, making the energy efficiency premium statistically insignificant in his work. Harrison and Seiler (2011) find that political ideology is correlated with the incidence of energy efficient rent premiums; regions that voted for the liberal candidate Barack Obama in the 2008 United States presidential election pay significantly higher energy efficiency premiums than regions that voted for the conservative candidate, John McCain.

Nearly all existing studies of energy efficiency premiums compare green- or energy efficiency-certified with uncertified assets. There are two potential problems with this approach. First, it presents the possibility that price premiums are based on the decision to certify as opposed to the characteristics of certification. The decision to certify may be correlated with environmental performance, but also on unobserved owner characteristics such as property management strategy or capability to secure investment capital. The second problem is that one can differentiate within the stock of green-certified assets but not within the stock of uncertified assets, effectively creating a truncated independent variable of interest. The point of truncation is usually set so that only the market leaders are identified; for example, Energy Star certification is only open to the top quartile of assets by energy consumption. This means that some uncertified assets may be very close to certification, effectively obtaining nearly all the intrinsic benefits of green building, while others much further away. Thus, existing studies comparing certified and uncertified assets are most likely measuring the price of market signalling.

The European studies suffer from the lack of a subjective measurement of asset quality in Europe, leading to the problem of endogeneity via omitted variable bias. In the United States, the Building Owners and Managers Association [BOMA] grade office assets as 'Class A', 'Class B' and 'Class C' according to popular perception of the services provided to tenants. Australia takes a similar approach, with well-defined criteria for each service quality threshold (Property Council of

Australia, 2006b). The lack of similar assessments in Europe leads Sedlacek and Maier (2012) to develop a theory that energy certifications in Europe are filling this niche of a metric for quality differentiation. As evidence, Sedlacek and Maier find that green building certifications are used in practice to proxy a range of features unrelated to energy efficiency, such as construction quality. Chegut *et al.* (2012) provide further support to the Sedlacek and Maier hypothesis by finding unusually high price premiums (near 30%) for green building certification in the UK, leading to a conclusion that their high premiums suffer from omitted variable bias and act as an instrument for asset service quality. Kok and Jennen (2012) argue that asset age can be a proxy for asset quality, but the insignificance and trivial contribution of their asset age variable coefficient belies the possibility that their model sees Dutch energy ratings as a better proxy for asset service quality.

The next subsection highlights two further concerns with existing econometric models of the effect of asset energy efficiency on rent prices in particular. These concerns are the subject of research in this thesis. First is the reliance on datasets at the asset scale to model the effect of lease transactions that occur at the tenancy scale. Second is a concern with the European studies in particular that strong regulatory policy, not free market transformation, may be responsible for rent price differentiation.

1.2.3 Research Gap: Market Effects of Energy Efficiency on Rental Price

This thesis finds new concerns with existing econometric models examining the effect of asset energy efficiency on office rental markets. As Table 1.2 demonstrated, tenant willingness to pay higher rent is a key argument for investment in energy efficient assets. However, as this section argues, the hypothesis that tenants are willing to pay higher rents has not been robustly tested in the existing literature.

First, most prior studies of energy efficiency rent premiums are conducted at the asset scale, which makes the causal factor unclear. Prior studies assume higher rent measured at the asset scale is sufficient to conclude tenants are willing to pay a price premium for energy efficiency (for example, see Reichardt *et al.*, 2012). However, higher rental rates are not necessarily the cause of a rent premium calculated at the asset scale. Converting a heterogeneous set of rental income streams from many individual contracts into one single rent value means asset-scale rent premiums can also arise from valuation bias, occupancy rates, occupancy distribution, or market timing.

For example, one metric representing rent at the asset scale is asking rent, the price advertised to the market by leasing agents. Early studies using the CoStar database in the United States, such as Eichholtz et al. (2010) and Fuerst and McAllister (2011b), use asking rent to measure rent. One problem with asking rent is a valuation bias that measures expectations, not outcomes. Leasing agents may systematically overvalue energy efficient labelled offices relative to unlabelled offices as a result of numerous industry publications taking the normative position that energy efficiency premiums should exist (Sayce *et al.*, 2010). Another problem is that asking rents are not independent of other variables associated with asset value. Notably, Glascock *et al.* (1990) find a very strong relationship between occupancy and asking rents. In the energy efficiency premium literature, there is evidence that asking rent is influenced by occupancy in the results of Eichholtz *et al.* (2010); they calculate an "effective rent" premium from the owner perspective by multiplying asking rent and occupancy rate. This premium is almost exactly equal to squaring their rent premium. Because their implied occupancy premium and measured asking rent premium are almost identical, the possibility that their asking rent premium already incorporates the occupancy premium cannot be rejected. Lastly, a third problem with the use of asking rents is that rents are a function of micro-locational factors within a building, such as floor level, so the rate depends on the particular tenancy that is vacant. Overall, in a survey of econometric techniques of representing rent prices, asking rent is the least reliable (McDonald, 2002).

An alternative metric of asset rent is a calculation of average rent (R_{avg}) taking the form:

$$R_{avg} = \sum_{i=1}^{N} p_i R_i \tag{1.5}$$

where R_i represents rent paid per unit of floor area by tenant *i* at time T (when data is captured for each asset) and p_i represents the fraction of space leased by tenant *i* relative to the total space covered by rental contracts in the same building known to the data provider. Different measures of rent can be used. For example, in the literature, Reichardt et al. (2012) use average gross rent to measure rent while Newell et al. (2011) use average net rent. Typically, gross rent equals net rent plus recoverable operating expenses. Net rent is typically used to represent rental income to the owner while gross rent can be used to represent the wider scope of accommodation costs facing the tenant.

In a review of office rent modelling methods, McDonald (2002) argues that average rent is one step better than asking rent. Since the data are agreed contract prices, the use of average rent removes valuation bias from agents. In addition, average rent can eliminate some influence from occupancy rates, though any significant difference in the micro-location of vacant space or rental rates not known to the data provider at the time of measurement could appear in an average rent differential. In the Reichardt *et al.* (2012) model, lagged occupancy rates are included to further control for the influence of occupancy on average rent.

However, an inter-temporal aggregation problem arises because rent paid by each tenant was negotiated at a unique time, with year-to-year increases often representing pre-negotiated rent inflation, not open-market rents. Since energy efficient buildings tend to be newer buildings (Kok and Jennen, 2012), the possibility that most were leased-up with market rents at a peak just prior to the recent Global Financial Crisis means energy efficient rent premiums may signal market timing as opposed to tenant demand for energy efficiency. Also, tenants may have signed leases before the building was formally identified as energy efficient, further weakening the assumed causal path of tenant willingness to pay for energy efficiency. No econometric study reviewed above attempts to control for inter-temporal aggregation.

A third metric for average rent is net operating income (R_{NOI}), used by Pivo and McNamara (2005). Net operating income is similar to the use of average net rent, but NOI includes the cost of vacant space by replacing p_i with p_{i_A}, the percentage of total building leasable area occupied by tenant *i*, and subtracts unrecoverable operating expenses at time T (U_T) per unit of leasable area (A) to arrive at a measure of net income accruing to owners:

$$R_{NOI} = \sum_{i=1}^{N} p_{i_A} R_i - \frac{U_T}{A} \qquad (1.6)$$

R_i must measure net rent paid by each tenant, not gross rent. Average net operating income is useful to measure a comprehensive outcome for owners, but not to determine the cause of the outcome. Average net operating income will be influenced by market timing, occupancy, and expenses unrelated to energy consumption.

If one is to test tenant willingness to pay for energy efficiency, it is necessary to construct models of leasing transactions. Three European studies are conducted using individual lease transactions (Chegut *et al.*, 2012, Fuerst *et al.*, 2013, Kok and Jennen, 2012), but all are difficult to interpret as an energy efficiency premium. The lack of a systematic method to control for asset service quality in Europe, as described in the previous section, is one problem. For example, Fuerst *et al.* (2013) finds that building age may be more important than energy ratings when the authors use variable interactions to explore why rent premiums appeared at both ends of the energy consumption spectrum. Another problem is the strong regulatory environment in Europe, where policy compliance may be the cause of rental premiums, not market demand for energy efficiency. For example, the highest premium observed by Kok and Jennen (2012) is for tenancies in C-rated buildings, not the more energy efficient A- or B-rated buildings; this is notable because the C-rating is a policy requirement for government accommodation procurement.

Thus a research gap exists for this study to robustly test the hypothesis that tenants are willing to pay higher rents, all else equal, for energy efficient office space. This study continues the theme described by Warren-Myers (2012) that improved data quality is critical to the progress of research on the market value of energy efficiency. Chapter 5 outlines the construction of an extensive dataset of lease transactions in central Sydney, a market with only minor government presence and a market where quality ratings and energy efficiency ratings are comprehensive. This dataset will be used to estimate a model of lease transactions to test tenant willingness to pay for energy efficiency in a competitive open market. The next chapter looks at green building in Australia in much more depth, including the reason why Sydney is an ideal choice for this study of lease transactions.

1.3 Summary of Objectives and Hypotheses

The review above sets up two complementary research projects. The first, which will be addressed in Chapters 3 and 4, is to understand empirically the role played by environmental performance market differentiation on existing asset energy consumption and associated greenhouse gas emissions. Section 1.1 found that literature on the environmental performance outcomes of market differentiation is largely theoretical, with the dominant assumption being that participation was sufficient to proxy outcomes. Specific objectives of this research are twofold: first, to understand the role that participation in repetitive energy performance plays on existing asset energy management and, second, to understand whether there is any difference in outcomes as a function of the mechanism for entry into repetitive energy auditing schemes (compulsory vs. mandatory). Literature from the management discipline suggests a hypothesis that asset managers will reduce energy consumption in the face of repetitive auditing, irrespective of the mechanism for entry into the scheme.

The second research project, which is addressed in Chapters 5 and 6, emerges from a much larger body of literature. Its objective is to construct a hedonic price model of office rents in a single market where environmental and asset quality differentiation is comprehensive. Most importantly, it will address rental prices at the lease contract scale – not the asset scale – to overcome a number of methodological limitations identified in Section 1.2.3 above. The literature on hedonic price models in green commercial office property markets is nearly unanimous in the argument that environmental performance is reflected in market value and rental value, with the most energy efficient assets gaining the highest premiums. Thus, it is expected that Sydney, the market chosen for this research, will behave similar; indeed, one existing study has found an energy efficiency rent premium in Sydney (Newell *et al.* 2011). By removing a number of limitations in the data collected by this previous study, one would expect the argument for private investment in energy efficient office property to strengthen.

Chapter 2

Green Building in Australia

The previous chapter presented a broad discussion of the interaction between the property industry and the concept of green building, identifying research gaps associated with asset energy efficiency outcomes and leasing market effects that will be addressed in this thesis using data from Australian commercial property markets. This chapter presents a background for green building in Australia, including the NABERS [National Australian Built Environment Rating Scheme] Energy tool that provides commercial office asset owners with the ability to differentiate their asset based on operational energy consumption.

Australia is an excellent context for studying the research gaps described in the previous chapter. As this chapter outlines, the NABERS Energy certification scheme, in use since 1999, is very useful. The performance audit methodology of NABERS Energy has not changed in the past 14 years, making longitudinal and cross-sectional comparisons valid. NABERS certifies all assets seeking certification, not just the top quartile, providing a non-truncated continuous variable measuring environmental performance. Mandatory disclosure commenced nationwide in 2011, ensuring that a sample of inefficient office assets are identified, although many inefficient assets engaged with NABERS Energy voluntarily before the mandate. For market analysis, Australian markets have very specific guidelines regarding asset service quality, a variable that is critically omitted from European studies looking at the relationship between rent and energy efficiency. With frequent NABERS re-certification, energy ratings vary while quality ratings stay relatively constant, enabling a model to distinguish between the two sources of property value. Finally, the author was able to access to over 1,500 publicly registered lease contracts in Sydney – Australia's largest and most competitive commercial office market – to create a database of lease transactions at the tenancy scale specifically for the purpose of this study.

In regard to the two driving factors motivating commercial office asset energy efficiency – mitigation of greenhouse gas emissions and energy cost inflation – Australia is roughly in-line with the global trends reported in Chapter 1. According to the most recent greenhouse gas inventory, the property sector is responsible for 23% of the nation's greenhouse gas emissions, split 13% and 10% respectively between residential and commercial (Centre for International Economics, 2008). The inventory notes that electricity consumption from coal-fired generation is the dominant source of greenhouse gas emissions from the Australian property sector and that anticipated growth in energy consumption is much faster in the commercial sector (2.1% growth in gross greenhouse gas emissions per annum) than the residential sector (1.3% growth in gross greenhouse gas emissions per annum). In line with Levine *et al.* (2007), energy efficiency is one of the cheapest and most accessible greenhouse gas mitigation strategies for Australia (Centre for International Economics, 2008). As for energy cost inflation, Chapter 1 used Sydney as an example of rising Australian electricity costs.

The first section of this chapter discusses the context of green building certification in Australia, particularly the NABERS Energy scheme. This is followed by a discussion of efforts by local, state, and federal governments to increase the private provision of energy efficient commercial assets, including the BEED [Building Energy Efficiency Disclosure] Act that introduced mandatory energy performance disclosure. The chapter concludes with a general overview regarding Australian commercial property markets, Sydney in particular, and how office asset quality is assessed in Australia.

2.1 Green Building Differentiation in Australia

Australia has followed the pattern narrated in Chapter 1 regarding the use of asset differentiation in a market-based transformation towards green building practices, including asset energy efficiency. Two distinct approaches have emerged to frame the green building market in line with the methods summarised in Table 1.1. For an asset rating targeted at the development and construction of new commercial office assets, the Green Building Council of Australia licenced the BREEAM [Building Research Establishment Environmental Assessment Method] methodology from the United Kingdom and developed a version for Australia called Green Star. For a performance rating targeted at existing assets, the state government of New South Wales developed the ABGR [Australian Building Greenhouse Rating] for differentiating greenhouse gas emissions. ABGR would later be branded as NABERS Energy when the scope of existing asset performance rating was expanded beyond energy-related greenhouse gas emissions.

Mitchell (2010) narrates a comprehensive history of green building certification and market differentiation in Australia over the past decade, including early efforts at strengthening the Australian building code. Warren (2009) discusses the initial market uptake of the three most common nationwide certification schemes: Green Star Office, NABERS Energy, and NABERS Water. The next two sections describe Green Star and NABERS, the key tools that frame the property industry's identification of green building in Australia. Although this thesis is exclusively interested in NABERS Energy ratings, it is useful to provide a context that includes Green Star, which uses asset ratings based on NABERS Energy to assess energy efficiency.

2.1.1 Green Star: Australia's asset rating scheme

Green Star is a formal green building assessment tool owned by the privately run Green Building Council of Australia. The first Green Star asset, 8 Brindabella Circuit in the Australian Capital Territory, was certified in late 2004 and constructed in 2005. Green Star is an asset rating scheme following the multiple-indicator voluntary building code framework (see Section 1.1.1.1). For the time period assessed in this thesis (1999 through 2013), only new construction projects qualify for Green Star differentiation. Starting in 2013, a "Green Star Performance" system modelled on the BREEAM In-Use tool was being prepared for market release[1].

Relative to overseas examples of green building asset ratings, Green Star is unique in that a development does not need to be constructed in order to be formally certified, as seen in the inaugural certification. Project owners can receive a "Design" rating based on planning documents. Overseas, post-construction is typically when green building assessments are performed. For example, LEED and BREEAM projects can only be certified at the Green-Star equivalent of "As-Built", which is certification immediately after the commissioning of a new asset.

The scope of green building attributes in Green Star is modelled after the initial BREEAM version 1/90 discussed in the previous chapter. Reflecting the holistic concept of global, local and indoor environmental concerns, Green Star assessment categories are: energy, transport, water, land use/ecology, indoor environment quality, emissions[2], material selection, and project management. In Green Star, new commercial building developers choose from a broad range of optional environmental standards in these categories and receive certification labels of "4-star", "5-star" or "6-star" based on the aggregate number of standards with which they comply. Higher star levels of certification are intended to communicate greater potential for market-leading environmental performance. In theory, it is possible to achieve lower scores of 1-, 2-, or 3-stars, but the Australian Green Building Council does not offer formal certification for these lower scores. This strategy matches BREEAM and LEED, which seek to only identify market leaders. A zero-star asset is assumed to be one that performs at the minimum standards required by the statutory building code.

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[1] As an example of the popularity of NABERS for performance ratings, only three assets have registered interest in Green Star Performance as of early 2014. This is a stark contrast with the rapid uptake of LEED for Existing Buildings: Operations and Maintenance, which is the Green Star Performance equivalent in the United States (Kok *et al.*, 2012b).

[2] "Emissions" refers to refrigerants, stormwater, light pollution, bacteria in reticulated water systems, and pollutants released in the manufacture of insulation products. Carbon dioxide emissions from energy consumption are assessed in the "energy" category.

While Chapter 1 showed asset rating schemes such as LEED, BREEAM and Green Star are commonly used in studies of the environmental and market effects of green building, this study chooses not to investigate Green Star ratings. The main reason is the coverage of NABERS, which vastly exceeds that of Green Star (see Figure 2.3 in Section 2.1.2). For example, in the Sydney office market studied in Chapters 5 and 6, there were only three office assets certified using Green Star with registered lease contracts while over 100 assets held valid NABERS certificates at the time of lease. The other reason is that energy efficiency in early versions of Green Star is assessed by simulating an expected NABERS Energy rating. Assessing energy performance directly overcomes the problems discussed in Chapter 1 associated with high variance between simulated asset ratings and measured performance ratings. The unique Green Star Design rating is most popular – accounting for over 75% of certified projects according to Mitchell (2010) – so Green Star is further detached from in-use performance than LEED or other green building assessments that simulate an asset rating post-construction.

2.1.2 NABERS: Australia's performance rating scheme

Performance rating in Australia began five years before Green Star was first released. According to Bannister (2012) the New South Wales state government sought to produce a tool in 1999 that measured both actual and potential greenhouse gas emissions from office buildings, but dropped the latter owing to the complexity involved in simulating an asset rating. The performance rating methodology that was implemented became known as the Australian Greenhouse Building Rating, or ABGR. Later, in 2006, the ABGR would be re-branded as NABERS Energy when the Australian Federal Government sought to produce performance ratings for all categories that were covered in the Green Star asset rating scheme.

Presently, an existing commercial office building can be certified in five areas of concern: operational energy-related greenhouse gas emissions (NABERS Energy), potable water consumption (NABERS Water), waste generation (NABERS Waste), operational transport-related greenhouse gas emissions (NABERS Transport), and indoor air quality (NABERS Indoor Environment). Only NABERS Energy and NABERS Water have achieved substantial market uptake, with the former being more popular than the latter. Unlike Green Star, ratings in each area of concern are independent and certified separately; there is no procedure to weight the various categories and produce a single NABERS rating. The scope of environmental sustainability in this study is energy efficiency and associated greenhouse gas emissions, so only NABERS Energy ratings are used to measure environmental performance; future research will consider the influence of NABERS Water.

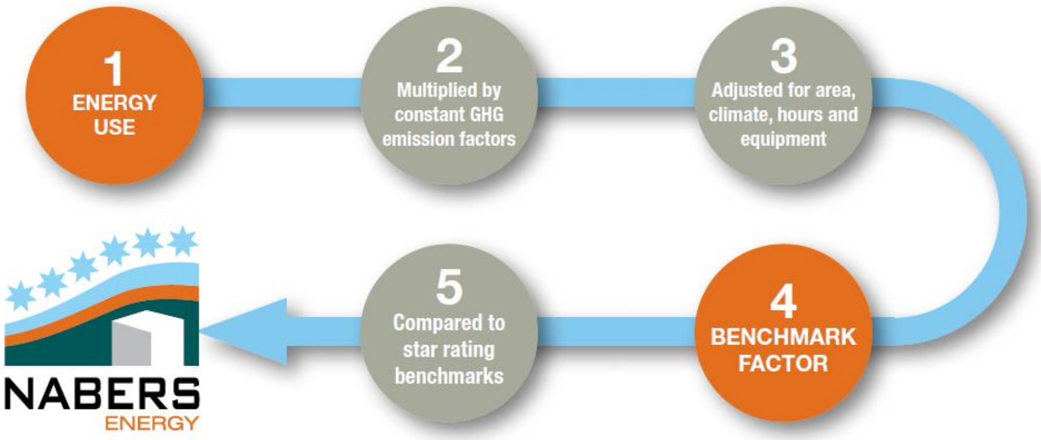

Figure 2.1. NABERS Energy certification process. Source: NSW Office of Environment and Heritage (2011a)

2.1.2.1 NABERS Energy Methodology

The assessment method behind NABERS Energy has remained constant since its inception as ABGR in 1999. Figure 2.1 presents a flow diagram of a typical certification process. First, an assessor audits a 12-month period of site energy consumption. Second, the raw energy consumption data is converted into greenhouse gas emissions based on each energy source. The greenhouse gas emissions are then divided by the asset's "Rated Area", a measure of floor area that takes into account vacancies over the assessed period, to produce a comparable metric of area-normalised greenhouse gas emissions. Further adjustments to this area-normalised figure are performed to account for city, climate, and intensity of asset use. The resulting figure is called a "benchmark factor" and compared with the median benchmark factor in each city to produce a star rating representing the asset's greenhouse gas emissions relative to other local assets. Extensive details on the methodology can be found in the detailed instructions given to NABERS Energy auditors (Department of Environment Climate Change and Water NSW, 2010).

0.............	Very poor
1.............	Poor
2.............	Below average
2.5 to 3....	Average
4.............	Good
5.............	Excellent
6.............	Market leading

Figure 2.2. NABERS Energy star rating thresholds and interpretation.

The benchmark factor is assigned a star rating in increments of half-stars between one and six stars based on its relative position within local market. If an asset does not reach the 1-star threshold, it is given a zero-star rating[3]. In theory, a rating of 2.5 or 3-stars is the market average, a zero-star rating represents exceptionally poor performance, and a 6-star rating represents market leadership[4] (Figure 2.2). NABERS disclosures are publicly available to anyone via the NABERS website (http://www.nabers.com.au).

What is of little dispute is the consistency of raw energy data collected by the NABERS Energy auditing process. The consistent guidelines regarding data collection boundaries and the calculation of Rated Area (Department of Environment Climate Change and Water NSW, 2010) is very useful in enabling cross-sectional comparison between assets as well as longitudinal comparisons over time. Chapter 3 describes how this study uses the raw energy data collected in each NABERS Energy audit to represent asset energy consumption.

2.1.2.2 NABERS Energy Assessment Boundaries

Three assessment boundaries exist for NABERS Energy. At the asset scale, building owners can choose to disclose their greenhouse gas emissions from “Whole Building” energy use or “Base Building” energy use. The former includes all energy consumed in the building while the latter is limited to services under the owner’s control: space conditioning, lifts, hot water and common area lighting. The third boundary is the “Tenancy” scope, which is limited to a particular tenancy to measure the services under the tenant’s control: tenant equipment (computers and other plug loads), tenancy lighting, and supplementary air conditioning services specific to one tenancy. In theory, the energy consumption measured in a Whole Building rating[5] equals the sum of the Base Building rating plus the sum of all Tenancy ratings. In an asset with k tenancies, this identity emerges:

$$Whole\ Building\ Energy = Base\ Building\ Energy + \sum_{i=1}^{k} Tenancy\ Energy_k \qquad (2.1)$$

Base Building Energy is the most popular scope. Because of highly standardised leasing structures in major Australian cities that require the tenants to pay operational energy costs

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[3] As a result of this methodological choice, there is no 0.5 star rating.

[4] There is no equivalence between a 4-,5-, or 6-star NABERS Energy asset and a 4-, 5-, or 6-star Green Star asset. Mitchell (2010) and Reed *et al.* (2011) discuss the potential for the market to be confused by the choice of NABERS and Green Star to use identically-scaled but completely unrelated star ratings to communicate green building credentials.

[5] Energy Star, the performance rating programme for office assets in the United States, is similar to the Whole Building scope of NABERS Energy.

specific to their tenancy (see Section 5.1.2.2), most office assets are sub-metered to sufficiently enable an auditor to exclude the tenant-specific power consumption. Sub-metering is not generally possible for other NABERS certifications, so the remaining four NABERS certification categories – Water, Transport, Waste, and Indoor Environment – are only assessed with the Whole Building scope.

2.1.2.3 Green Power Offsets

NABERS Energy aims to incentivise investment in operational energy efficiency. But it also enables assets to meet zero-greenhouse gas emission targets through offsets acquired by purchasing "Green Power" from the local utility company. Electricity purchased as Green Power is calculated as having zero greenhouse gas emissions.

Green Power is a national initiative managed by the Australian Federal Government that allows an electricity consumer to pay a premium for electricity that goes to renewable energy producers in exchange for certification that the consumer's electricity was generated by renewable energy. When an owner elects to purchase Green Power to improve his NABERS Energy rating, the certificate includes star ratings with and without the Green Power purchase.

Offsets purchased through Green Power only affect an asset's benchmark factor and its star rating. Raw energy data collected during the NABERS audit is unaffected by the decision to purchase Green Power. Many public policies associated with NABERS Energy ratings, such as mandatory disclosure under the Building Energy Efficiency Disclosure Act (see Section 2.2) require ratings to exclude Green Power, thus the use of Green Power offsets is unpopular and used in only 13% of all certificates gathered for this study.

2.1.2.4 NABERS Energy Market Uptake

In the early years of NABERS Energy, certification was only open to office assets in the states of New South Wales, Victoria, and the Australian Capital Territory. Once benchmarking protocols were set up to include other states in 2003, all states could participate.

Bannister (2012) cites two influential policy decisions that subsequently embedded NABERS Energy in the Australian property market. First were general government procurement targets that set aspirational rating floors for government accommodation. These policies likely influenced the decision of major property investment firms to pursue leadership in corporate social responsibility (Bauer *et al.*, 2011) as a means of attracting large, long-term and less risky government tenants. Second was the Building Energy Efficiency Disclosure Act in 2010, which implemented mandatory disclosure of NABERS Energy ratings (excluding Green Power offsets) at the time of sale and lease. Section 2.2 below describes these and other policies that have influenced investment in office asset energy efficiency.

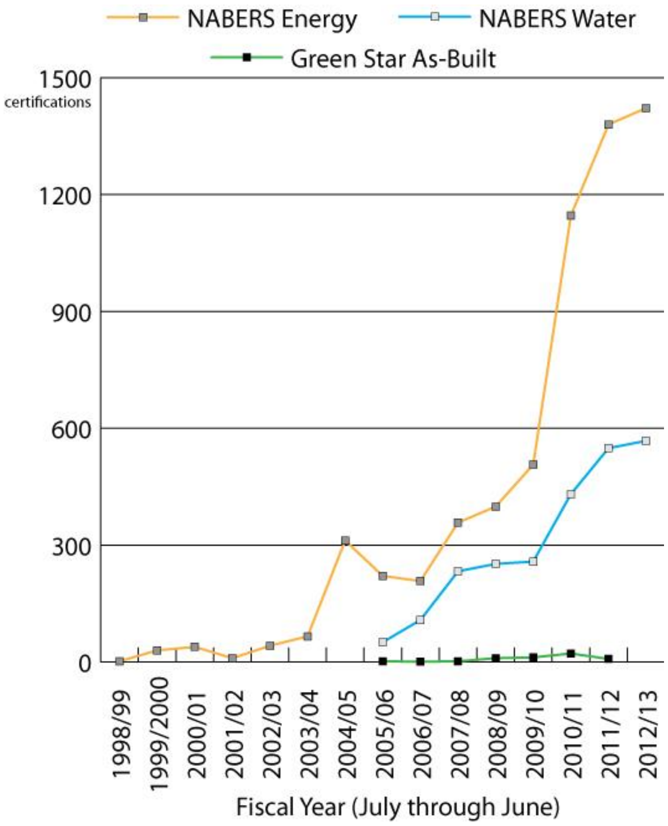

Figure 2.3. Uptake of NABERS and Green Star As-Built over time. NABERS Data from Grosskopf (2013).

According to the first NABERS Annual Report (Grosskopf, 2013), 19 million square metres representing approximately 72% of all Australian office assets by floor area were NABERS Energy certified in 2012. Figure 2.3 graphs the annual number of NABERS certification applications each fiscal year, as reported by Grosskopf (2013), and, for context, the number of Green Star As-Built certifications. The relative scale between NABERS and Green Star demonstrates how important existing assets are to the impact of the property sector on the environment.

2.2 Green Building in Australian Public Policy

As the discussion on market uptake noted, public policy decisions tied to the use of NABERS Energy have contributed to its growth in Australian property markets. As a public good, environmental quality is traditionally the domain of regulation, but Chapter 1 described how market-based policies are becoming popular as an alternative (Borck and Coglianese, 2009). This section discusses three policy measures that attempt to stimulate the market for asset energy efficiency by influencing supply and demand for green buildings. First, government procurement initiatives set NABERS Energy rating floors. Second, financial grants and unique funding mechanisms have been developed to provide capital for green building investment. Third, mandatory disclosure was introduced to maximise the participation rate in NABERS Energy.

2.2.1 Government Procurement and Green Leases

As one of the largest tenants of office space, governments have set energy efficiency rating floors for office accommodation. An example of this practice is the Australian Federal Government's Energy Efficiency in Government Operations (EEGO) policy, which requires large government tenancies to lease office space in buildings with a NABERS Energy rating of at least 4.5-stars. In addition, all Australian states except Tasmania have an energy efficiency rating floor for state government agencies, ranging from 3.5 stars to 4.5 stars (NSW Office of Environment and Heritage, 2011b). Because government tenants are expected to require large areas, commit to long lease terms and be at low risk of default, Bannister (2012) argued that these procurement policies are responsible for the first surge in NABERS Energy rating seen around 2005/2006 in Figure 2.3.

The EEGO policy also requires government tenants to negotiate "Green Lease" clauses when arranging a new office lease. A Green Lease is a section in a typical lease contract between tenants and landlords that specifies energy targets and other environmental performance goals, including each party's responsibilities towards meeting these targets (Hinnells *et al.*, 2008). Green Leases can be "light green" if these clauses simply act as a memorandum of understanding between the parties, with failure to achieve goals or perform duties not considered to be a breach of the lease. The alternative is a "dark green" lease, wherein penalties are specified for failing to act in compliance with the Green Lease obligations.

In the author's experience with the Australian market, EEGO and other government green building procurement policies are best described as statements of aspiration. This thesis provides some empirical evidence that rating floors are often ignored and Green Leases drafted according to the "light green" approach. For example, six leases in the lease database constructed in Chapter 5 are for New South Wales state government agencies; only one is for accommodation in a NABERS Energy 4.5-star asset, the rating floor specified by the state. Section 6.3.1 discusses the prevalence of "light green" lease contracts in Sydney.

Nevertheless, these EEGO policies are almost certain to have influenced owners of existing office assets, who must assume that governments will act according to their aspiration. In the first major study of the market effects of NABERS Energy on the Australian property market, Newell *et al.* (2011) included the national capital, Canberra, which demonstrated the strongest relationship between energy efficiency and indicators of property value. This leaves little doubt that by altering the demand for a major office tenant, EEGO has influenced investment in asset energy efficiency.

2.2.2 Financial Incentives and Taxation

To further influence investment in asset energy efficiency, governments have intervened in capital markets. At the federal level, between 2008 and 2011, the contestable "AusIndustry Green Building Fund" distributed A$127.6 million in grants to private commercial building owners that pledged to invest in capital improvement projects to reduce operational greenhouse gas emissions. Grants were capped at A$550,000 per project and distributed 20% up front, 60% following project completion, and the final 20% after the asset had obtained a NABERS Energy certificate to assess the efficacy of the investment (AusIndustry, 2011). Similar grant-based initiatives using public funds to incentivise asset energy efficiency retrofits occurred in some states, notably in Victoria through the Sustainability Fund. Instead of providing capital directly to asset owners, the state-based funds tend to subsidise small, local, firms engaged in the supply of energy efficient technologies to asset owners.

Starting in 2012, financial incentives provided by government for private investment in asset energy efficiency switched from allocating grants to administering below-market cost loans. The main framework for this approach to funding energy efficiency upgrades in Australia is an Energy Upgrade Agreement, in which loan capital is repaid with property tax assessments to provide added lender security. As tax assessors, local municipal governments are responsible for policies that enable Energy Upgrade Agreements, so there is a diversity of structures across different municipalities in Australia. Blundell (2012) presents a thorough review of the development and implementation of Energy Upgrade Agreements in Australia.

Energy Upgrade Agreements have two objectives. First, the use of property tax assessments in repayment is expected to reduce the cost of capital because the repayment liability remains with the asset, not the owner. Future owners must repay any tax arrears, reducing the risk to the lender. Second, the finance and property industries have concluded that split incentives – owners pay for capital upgrades while tenants benefit from resulting operational improvements – is a barrier to capital investment in asset energy efficiency (Galuppo and Tu, 2010, David Gardiner & Associates, 2010, Kok *et al.*, 2012b). In Australian office leases, tenants are responsible for payment of their share of property tax assessments, either directly (net leases) or as part of their annual rental payment (semi-gross leases[6]). Thus, current and future tenants fund the capital improvement. However, Blundell (2012) notes some municipal governments limit tenant liability to a pre-agreed amount, usually the expected savings from the investment.

While financial incentives are the preferred vehicle of government intervention in capital markets, Australian governments have also used the more traditional method of taxation. The Australian federal government is one of the first capital-intensive countries to institute a direct tax on greenhouse gas emissions though the Clean Energy Bill 2011, which took effect at a fixed price of A$23 per tonne on 1 July 2012. This "carbon tax" inflates the cost of energy consumption, speeding up the energy cost inflation trend discussed in Section 1.1 as one of the two key motivations for the property sector to invest in operational asset energy efficiency.

2.2.3 Mandatory Energy Performance Disclosure

While government procurement initiatives discussed above led to the first spike in NABERS Energy participation rates, mandatory disclosure is responsible for the second, much larger, increase. Section 1.1.1.2 noted that Australia has been a global leader in the use of mandatory energy rating disclosure to influence demand for energy efficient property assets starting with the Australian Capital Territory mandating asset ratings for the residential sector in 1999. For office assets, consultation on a national policy of mandatory energy performance disclosure began in 2008. The resulting Australian Building Energy Efficiency Disclosure (BEED) Act was passed into law in June 2010 and commenced in November 2010 on a provisional basis (no penalties could be assessed). Full implementation, including penalties for non-compliance, began in November 2011. The BEED Act is the first global test of mandatory environmental performance disclosure in the property sector as a response to environmental problems.

The BEED Act requires two disclosures when advertising an office property for sale or lease. The first is the disclosure of a valid NABERS Energy rating, either Base Building or Whole Building scope. The second disclosure, which is not used in this thesis, is a detailed audit of the lighting technology installed in each tenancy. Both disclosures are combined in a document freely available on the government's Building Energy Efficiency Register (http://www.cbd.gov.au). In this thesis, the combined disclosure on the Building Energy Efficiency Register will be referred to as a BEED Act certificate. The validity of a BEED Act certificate is identical to the validity of the NABERS Energy certificate used in the disclosure.

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[6] A semi-gross lease integrates a base year of operating expenses into face rent, with the tenant liable for any increases over this base year. This semi-gross construction is much more common in Australia than traditional gross, or "full-service", leases where the tenant is not liable for the subsequent increases. See Chapter 5 for more on Australian office lease structures.

Figure 2.4. The prominent disclosure of NABERS Energy ratings is seen at this Sydney asset. The left image was captured a few weeks before enforcement of the BEED act commenced, while the right image is soon afterwards.

As a tool to inform the market, a large part of the text in the BEED Act specifies exactly how assets are to display NABERS Energy ratings in advertisements for sale or lease. Star ratings must be prominent and equivalent in font size to other advertised characteristics. Figure 2.4 shows an advertisement before and after enforcement of mandatory disclosure, demonstrating how obvious NABERS Energy ratings, even poor ones, are to any prospective tenant. Open public access to the underlying audit is also a key improvement on other mandatory disclosure regulations; Andaloro *et al.* (2010) documents that Energy Performance Certificate disclosures in many European states are very difficult to access because prospective tenants must actively pursue the information and often are not informed of the rating until after the transaction is complete.

A number of office assets are exempt from mandatory disclosure under the BEED Act. Small office assets leasing less than 2,000 square metres are not required to comply. Non-corporate building owners and buildings divided into strata titles are also exempt. The reason behind the exemption of non-corporate owners is that the Australian Federal Government is not empowered to regulate individuals; only state governments can force individuals to comply with regulations. However, the federal government does have the power to regulate corporations. Lastly, new office assets are exempt from disclosure for the first two years of occupation.

2.3 Australian Office Markets

Australia is a large country, with a land area of approximately 7.7 million square kilometres. However, over 80% of its 20.7 million people lives in the eight state and territory capital city metropolitan areas: Sydney, Melbourne, Brisbane, Canberra, Perth, Adelaide, Hobart, and Darwin (Australian Bureau of Statistics, 2008). Hence Australia is a highly urbanised society with well-developed commercial office markets. Table 2.1 describes the best estimate of the relative size of commercial office markets by state and the most recent census data on "white-collar" employment, which is the best proxy of demand for office accommodation[7].

This section describes trends in Australian office property markets during the time period of this study, 1999 to 2013. Sydney, Australia's largest city that is used for the case study in Chapters 5 and 6, is then explored in greater depth. Lastly, an overview of Australia's thorough rating of office asset service quality concludes this chapter.

Table 2.1. Office asset stocks and white-collar employment by Australian state. Percentage of total in brackets.

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Total Office Stock * (NLA x1000)	2,719 (10.4%)	9,551 (36.4%)	211 (0.8%)	4,084 (15.6%)	1,581 (6.0%)	384 (1.5%)	5,496 (20.9%)	2,227 (8.9%)	**26,253**
White-collar employment (x1000) **	174 (2.6%)	2,146 (31.8%)	67 (1.0%)	1,316 (19.5%)	486 (7.2%)	140 (2.1%)	1,713 (25.4%)	703 (10.4%)	**6,745**

* Capital city CBD areas and large suburban office parks only. Source: Grosskopf (2013).
** Source: Australian Census 2011.

2.3.1 Market Cycle Statistics

Investment Property Databank (IPD) is a private property market data club that aggregates market data provided by its members, which constitute most institutional commercial office asset owners in Australia. The firm produces helpful indices of investment performance variables that track overall market trends, including a "green index" that groups assets by NABERS rating (IPD, 2014). This green index report outlines the methodology behind the indices, which track total investment return as the sum of capital return and income return. Both capital return and income return are calculated monthly, using appraised values for capital value and measured income receipts for income return. These indices will be used to describe trends across Australian commercial office property markets for the relevant time period of this study.

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[7] The definition of white-collar employment is taken directly from the Australian census, and aggregates the following occupations: managers, administrators, professionals, clerks, sales persons and personal service workers.

For overall property market trend data, Figures 2.5 and 2.6 present total investment return for office markets in capital city central business districts (CBD) and selected suburban markets[8] respectively for the period June 1999 through June 2011. From these charts, two trends emerge. First is the relative consistency in total investment return amongst most CBD markets and suburban markets; a 10% per annum return (capital value plus income) appears to be a modal market return for Australian property ownership. Before and after the Global Financial Crisis that affected Australian property markets in 2008, returns were slightly higher and then much lower than the stable return, respectively. Significant deviations from the overall Australian office market trend occur in Perth and Brisbane (and to a somewhat smaller degree in one suburban Sydney market), which experienced abnormally large investment return just prior to the Global Financial Crisis. A look at rental return data (IPD, 2011) shows no difference between Perth or Brisbane and other major Australian markets, so the increase in investment return was entirely the result of an asset price boom. The likely cause of the asset price increase in these two cities is a mining boom in Western Australia and Queensland during this time period, which saw increased demand for office accommodation in these capital cities and very low vacancy rates.

In regard to the "green index" produced by IPD (2014), the firm finds evidence that "high NABERS Energy rated" assets (4 to 6 stars) in Australian CBD markets generate higher investment returns than "low NABERS Energy rated" assets (0 to 3.5 stars) as measured in calendar year 2013. Capital value return is responsible for the difference, with income return relatively constant across all CBD markets. For example, in Sydney CBD, income return was roughly 7% per annum for all assets in the IPD database, while total investment return was only 7.4% in 0 to 3.5 star assets and 10.5% in 4 to 6 star assets. This pattern of energy efficiency premiums roughly corresponds to the Newell *et al.* (2011) econometric study, but it is not appropriate to compare the two studies because the Newell study controlled for hedonic asset characteristics (size, age, and service quality, for example) while the IPD index figure is representative of a descriptive statistic for each city.

2.3.2 Sydney

As Australia's largest city, Sydney has a mature and highly competitive office market. The Property Council of Australia (2011) reports that in the first half of 2011, four office submarkets in the Sydney CBD contained 4.8 million m^2 of office space. In context, this is approximately half of the office space in major urban and suburban markets across the state of New South Wales, and slightly less than one-fifth of all major office markets in Australia (see Table 2.1).

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[8] North Sydney, Chatswood, Crows Nest, St. Leonards, Parramatta, and North Ryde are all suburban centres in metropolitan Sydney.

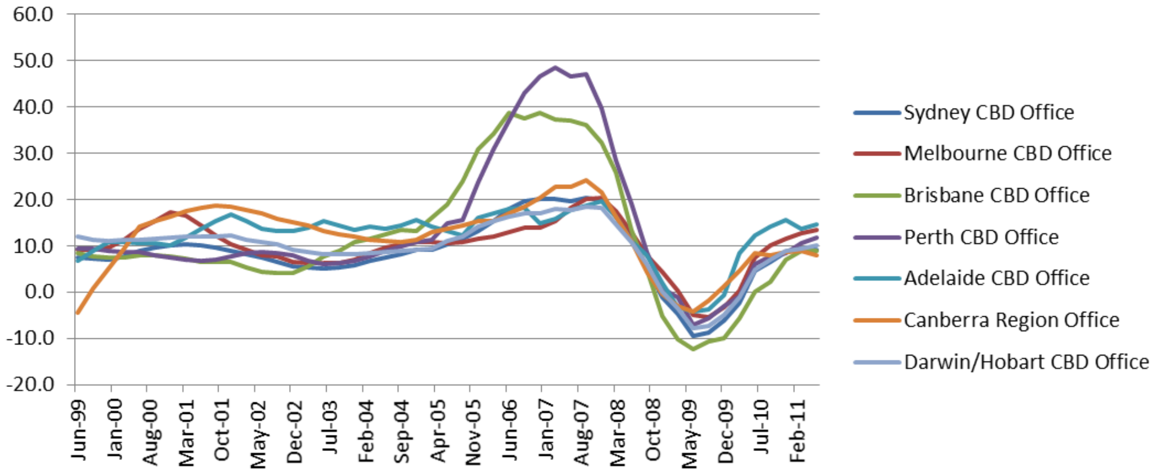

Figure 2.5. Central business district (CBD) office market trends: total investment return. Left axis measures percentage per annum. Data Source: IPD (2011).

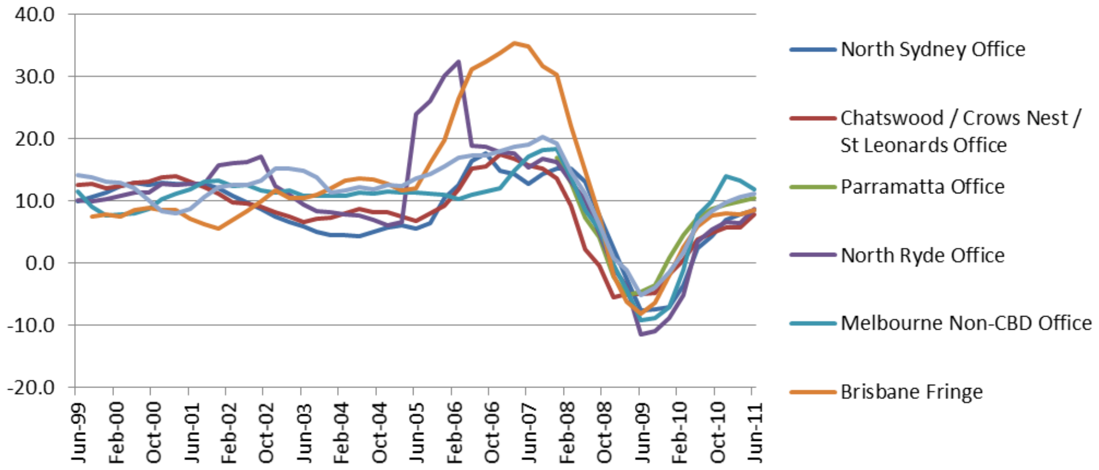

Figure 2.6. Selected suburban office market trends: total investment return. Left axis measures percentage per annum. Data Source: IPD (2011).

Demand for office space in the Sydney CBD is dominated by the financial services sector. Figure 2.7 describes the business sector of a sample of 940 office tenants that, together, leased 871.5 thousand m^2 of office space in the Sydney CBD (nearly one-fifth of total space). This sample will later be used in Chapters 5 and 6 to understand the effect of asset energy efficiency on tenant rent bids[9]. By area, the financial services sector occupies one-third of Sydney office space. Staff recruitment agencies (human resources) and information technology firms are also large private users of central Sydney office space. In particular, there are many recruitment agencies that lease small office areas.

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[9] The sample in Figure 2.7 (N=940) is greater than the lease database constructed in Chapter 5 (N=673) because Figure 2.7 contains leases in assets that were not NABERS Energy-certified at the time of lease.

Despite being the capital city of New South Wales, many state government agencies are housed in suburban markets, particularly in the suburb of Parramatta. Only 12% of Sydney accommodation (by area) is let to local, state, and federal government agencies. This reduces the influence of aspirational government accommodation energy rating floor policies (see Section 2.2.1) and will assist to understand how asset energy efficiency is traded in a competitive open market.

Figure 2.5 presented a trend of investment return in Sydney CBD office assets. However, office vacancy rates (Figure 2.8) best exemplify the market cycles experienced during this study period. Peaks in the market cycle were reached in late 2000 and again just before the Global Financial Crisis at the end of 2007. The market troughs in 2005 and 2012 are just barely worse than a 20-year historical average, indicating that vacancy in the Sydney office market is better than average for most of the time period featured in this thesis. As for other market indicators, rent statistics for the Sydney CBD are explored further in Chapters 5 and 6. For other market indicators associated, most large property brokerage firms publish regular reports on the central Sydney market (for example, Colliers International Research, 2012; Knight Frank Research, 2013).

The ABGR certification system, which became NABERS Energy, was first developed in New South Wales. Thus, market penetration of NABERS Energy is high in Sydney. As of April 2012, 182 unique office buildings in central Sydney had been NABERS Energy certified at least once. Grosskopf (2013) estimates that these assets represent 80% of the market by floor area.

2.3.3 Asset Quality Ratings

The Property Council of Australia (2006) publishes guidelines for ratings of “Premium”, “A-grade”, “B-grade”, “C-grade” and “D-grade” to differentiate subjective asset quality in the market. These ratings standardise the quality of services provided to tenants, such as lift frequencies, emergency power availability, asset management presence, communications technology, security, car parking, ventilation, and floor plate size. Importantly, asset quality ratings are detached from energy efficiency ratings; according to the guidelines in place during this study, Premium, A-, and B-grade assets only need to have obtained a NABERS Energy rating. There is no requirement regarding a particular NABERS Energy star rating threshold[10].

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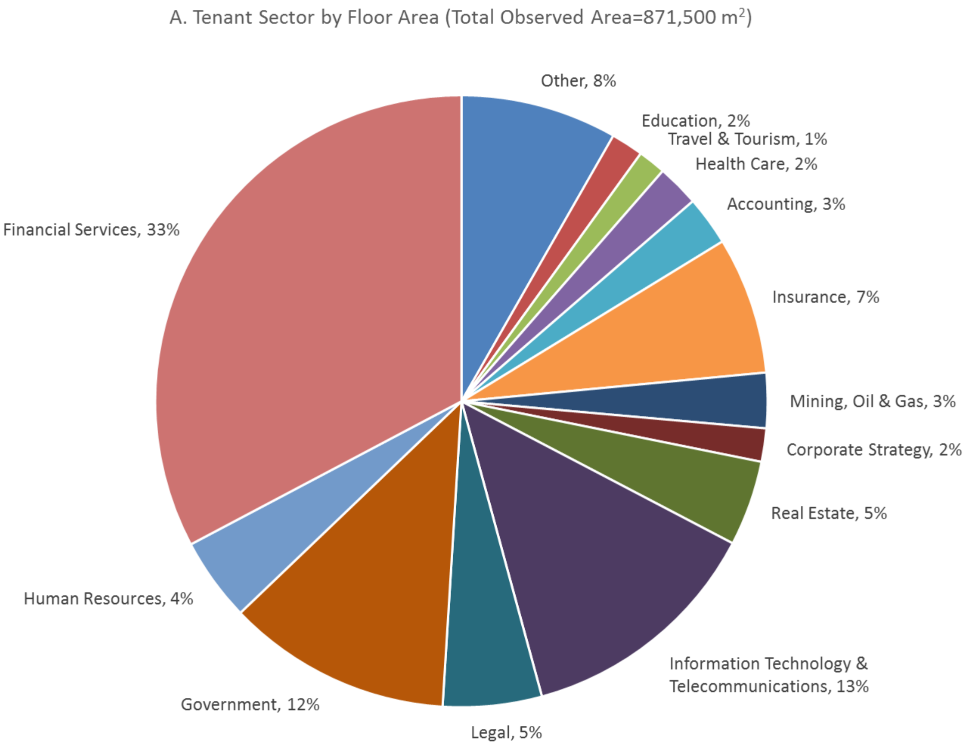
[10] Descriptive statistics of central Sydney assets presented in Chapter 5 show that NABERS Energy ratings in Premium grade assets tend to be poor and below average (see Table 5.4).



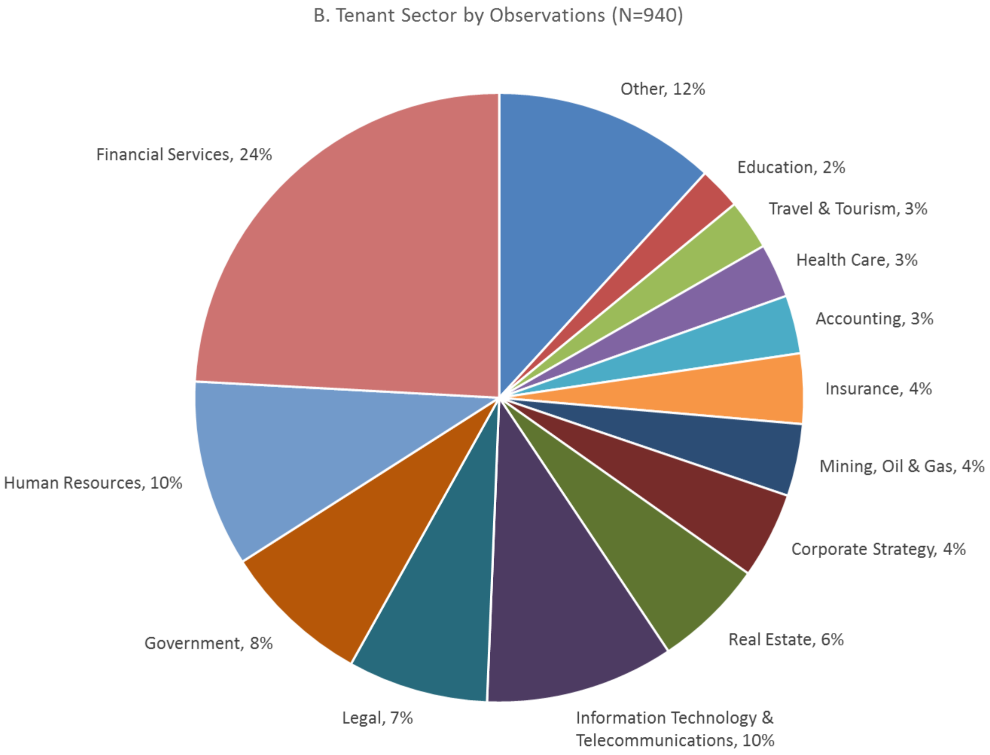


Figure 2.7. Business sectors in the Sydney CBD commercial office property market as measured by a random sample of 940 lease transactions registered on a land title between 2009 and 2011.

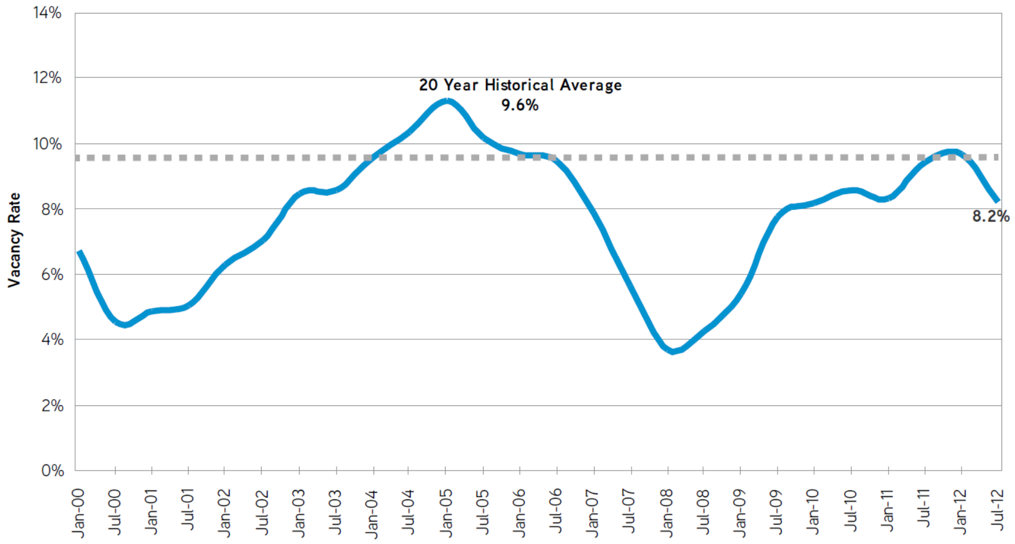


Figure 2.8. Sydney CBD office vacancy over the period of this study. Source: Colliers International Research (2012)

Table 2.2 lists the factors that make up existing asset quality ratings by rating threshold. In general, lower grades are defined as assets lacking the services specified for higher grades, so a D-grade asset is defined as lacking the services to qualify it as a C-grade asset. In theory, to qualify for a higher quality rating threshold, an asset owner must meet all the criteria for that higher grade so asset quality is a binary outcome. Table 2.2 only lists the general performance areas assessed; performance standards within each area increase as grades increase. For example, average lift wait times must be less than 40 seconds in C-grade assets, less than 35 seconds in B-grade assets, less than 30 seconds in A-grade assets, and less than 28 seconds in Premium assets. Consult the Property Council of Australia (2006b) for other detailed specifications.

Besides the technical specifications listed in Table 2.2, the Property Council of Australia (2006b) includes some subjective criteria in each rating. B-grade assets must have “a good standard of finish and maintenance”. A-grade assets must have “good views, outlook, and natural light”; “good quality lobby and lift finishes”; “good access from an attractive street”; “good quality lift ride”; and “high quality presentation and maintenance”. Premium assets must have “expansive views”; “ample natural lighting”; “prestige lobby and finishes”; “prestige-quality access”; “high quality lift ride”; and “premium presentation and maintenance”.

With Australia’s comprehensive system of asset quality rating along with high industry uptake of NABERS Energy ratings thanks to mandatory disclosure and other government policies discussed earlier, Australia is an ideal place to examine the environmental and property value implications of market differentiation as a strategy to improve asset energy efficiency. Chapter 3 begins the investigation of environmental outcomes from participation in NABERS Energy.

Table 2.2. Scope of Australian asset quality ratings. Data Source: Property Council of Australia (2006b)

Premium	A-Grade	B-Grade	C-Grade
Mechanical Services	Mechanical Services	Mechanical Services	Mechanical Services
Tenant Power Capacity	Tenant Power Capacity	Tenant Power Capacity	Tenant Power Capacity
Lift Wait Times	Lift Wait Times	Lift Wait Times	Lift Wait Times
Lift Capacity	Lift Capacity	Lift Capacity	Lift Capacity
Security System	Security System	Security System	Security System
Security Patrols	Security Patrols	Security Patrols	Security Patrols
Lighting Power Levels	Lighting Power Levels	Lighting Power Levels	
Professional Asset Mgmt.	Professional Asset Mgmt.	Professional Asset Mgmt.	
Tenant Data Risers	Tenant Data Risers	Tenant Data Risers	
Water Sub-metering	Water Sub-metering	Water Sub-metering	
Security Cameras	Security Cameras	Security Cameras	
NABERS Energy rated	NABERS Energy rated	NABERS Energy rated	
Outside Air Provision	Outside Air Provision		
Goods (Service) Lifts	Goods (Service) Lifts		
Emergency Services	Emergency Services		
Mobile Phone Coverage	Mobile Phone Coverage		
Fire Stair Access	Fire Stair Access		
Showers	Showers		
Attached Car Park	Attached Car Park		
Loading Bays	Loading Bays		
Asset Size Minimums	Asset Size Minimums		
Floor plate Minimums	Floor plate Minimums		
Mechanical Automation			
Kitchen Exhaust			

Chapter 3

Environmental Effectiveness: Data and Methodology

The introduction of NABERS [National Australian Built Environment Rating System] certification in Australia has made it possible to track measured site energy consumption over time in hundreds of existing office building assets. Prior to the commencement of voluntary energy certification in 1999, natural resource consumption was private information and, when voluntarily disclosed, was not fit for use in academic research because reporting and methods were *ad hoc*. By harmonising data collection methods, NABERS has made it possible to answer research questions associated with measured environmental performance outcomes in the Australian office building stock.

This chapter outlines the data and methods that will address two research questions associated with the introduction of NABERS certification outlined in Sections 1.1.3 and 1.1.4. The first of these questions is whether market differentiation via repetitive energy consumption auditing, the strategy employed by NABERS Energy to reduce greenhouse gas emissions, influences site energy use in existing office building assets. The method presented in this chapter calculates the effect per participant[1] in the environmental effectiveness framework developed by Borck and Coglianese (2009), who argue that the product of participation rate and effect per participant, plus spillover effects accruing to non-participants represent the outcome of a market intervention (see Section 1.1.2). In this study, the intervention is the introduction of repetitive energy auditing, with the degree of intervention measured as number of certificates obtained. Models are then presented that will be used in Chapter 4 to estimate the change in energy consumption between two NABERS Energy certificates, one obtained in period s and a benchmark representing the first certificate obtained in period 1:

$$Effect\ per\ asset = \Delta Consumption = Consumption_s - \ Consumption_1 \qquad (3.1)$$

The second research question is whether energy performance outcomes per asset from a panel of voluntary adopters differ from a panel of mandatory adopters when comparing the two groups. As Chapter 1 described, this question is highly relevant to the formulation of public policy associated with greenhouse gas mitigation in existing commercial building assets. Chapter 2 discussed the policy context in Australia, where the BEED [Building Energy Efficiency Disclosure]

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[1] A participant in the context of this chapter is a single asset that obtains NABERS Energy certification at least twice.

Act has recently mandated the advertisement of a NABERS Energy rating prior to sale and lease transactions in large office buildings. This chapter produces three definitions of mandatory adopter that are used in Chapter 4 to compare voluntary and mandatory adopter performance.

The first part of this chapter discusses the compilation of NABERS Energy data gathered to answer these two research questions. Section 3.2 describes this dataset statistically, while sections 3.3 and 3.4 develop empirical methods to evaluate the effect per asset for buildings in Australia that have obtained multiple NABERS certificates. A brief summary of the model specifications are provided in section 3.5. Chapter 4 presents and discusses the estimation of these models.

3.1 Data

The primary data for this research are extracted directly from a comprehensive collection of ABGR [Australian Building Greenhouse Rating][2] and NABERS certificates issued over the past 14 years and compiled by the author. All publicly available ABGR certificates and NABERS certificates have been obtained from the internet (http://www.abgr.gov.au for early ABGR certificates and http://www.nabers.com.au for later NABERS Energy certificates). Certificates were obtained from these sites since the commencement of ABGR in 1999 up until April 2012. Additional NABERS Energy certificates issued between April 2012 and the end of October 2013 were obtained for assets complying with BEED Act disclosure regulations. These compliance documents, which will be referred to as “BEED Act certificates”, are published on the commercial building disclosure website (http://www.cbd.gov.au) and include a full NABERS Energy certificate. In summary, the full NABERS Energy dataset spans between August 1999 and October 2013.

To ensure a sufficient number of observations for robust statistical interpretation, only the popular NABERS Base Building Energy accounting scope is used. The alternate accounting scopes, Tenant Energy and Whole Building Energy, do not have sufficient panel data for statistical tests, so the term “energy dataset” in this thesis refers solely to a collection of Base Building ratings.

Figure 3.1 is an example NABERS Base Building Energy certificate. Two star ratings are provided; one excludes the effect of greenhouse gas reductions obtained through the purchase of Green Power offsets. To describe underlying performance data captured in an audit, each certificate includes the percentage of electricity purchased with Green Power offsets, a calculation of overall

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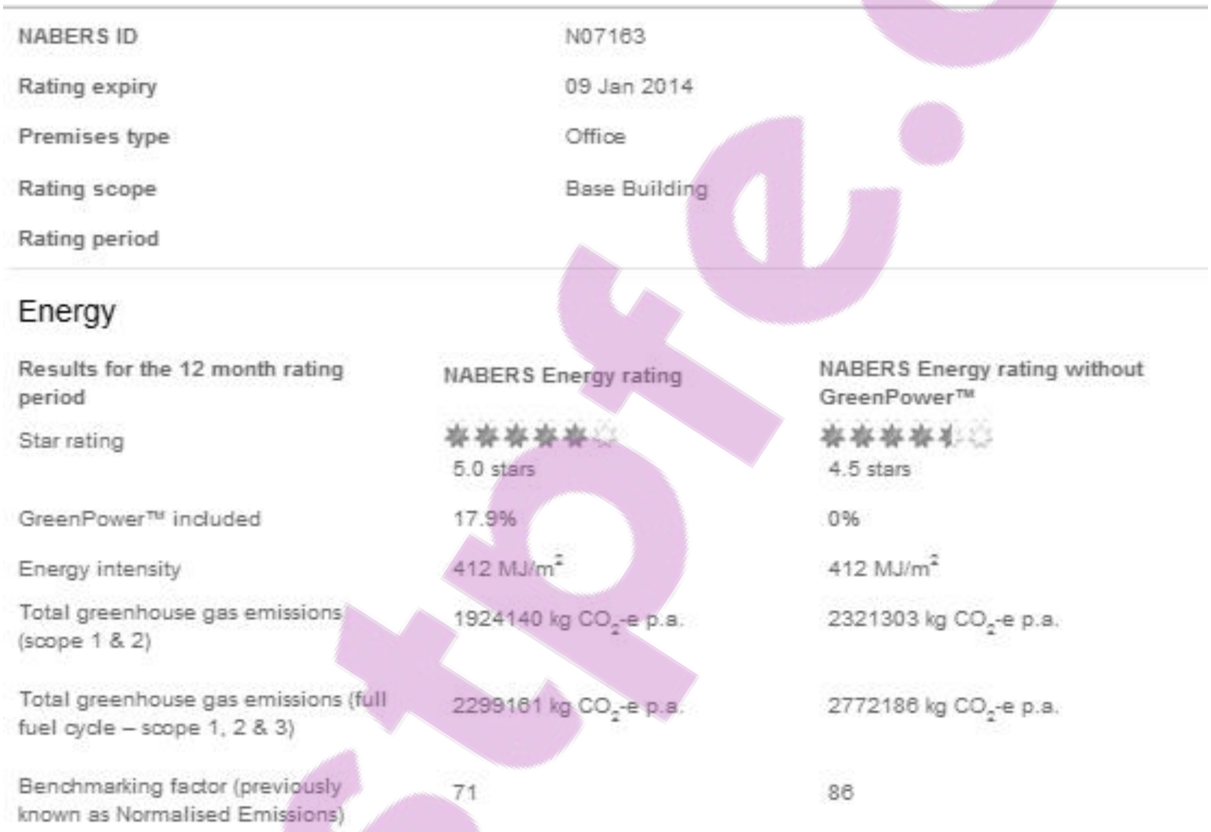
[2] ABGR was the original brand name of the NABERS Energy methodology. See Section 2.1.2.

building energy use intensity in MJ/m^2/year that is unaffected by Green Power, and two calculations of greenhouse gas emissions based on the Greenhouse Gas Protocol accounting framework (World Resources Institute and World Business Council for Sustainable Development, 2004). These raw data are converted into a “benchmark factor” that takes into account unreported background information: the number of hours per week the asset is in full operation and local climate indices. The specific calculation methodology of the benchmark factor has never been publicly disclosed. The benchmark factor is used to calculate the number of stars given to an asset, with a regional scale based on 2.5 stars as the median benchmark factor in each region of Australia. For a thorough methodology of raw data collection techniques and boundaries for NABERS performance audits, consult the guidelines provided to auditors (Department of Environment Climate Change and Water NSW, 2010).



NABERS ID	N07163
Rating expiry	09 Jan 2014
Premises type	Office
Rating scope	Base Building
Rating period	

Energy

Results for the 12 month rating period	NABERS Energy rating	NABERS Energy rating without GreenPower™
Star rating	★★★★★☆ 5.0 stars	★★★★⯪☆ 4.5 stars
GreenPower™ included	17.9%	0%
Energy intensity	412 MJ/m^2	412 MJ/m^2
Total greenhouse gas emissions (scope 1 & 2)	1924140 kg CO$_2$-e p.a.	2321303 kg CO$_2$-e p.a.
Total greenhouse gas emissions (full fuel cycle – scope 1, 2 & 3)	2299161 kg CO$_2$-e p.a.	2772186 kg CO$_2$-e p.a.
Benchmarking factor (previously known as Normalised Emissions)	71	86

Figure 3.1. Example Base Building NABERS Energy certificate.

After obtaining each certificate, it is necessary to organise and clean the data. Multiple certificates for the same asset with the same expiry date are removed to eliminate duplicates, with the chosen certificate having the highest NABERS identification number (a proxy for the issue date). A small number of certificates are missing data that clearly identifies the certified asset or were issued to represent performance across a portfolio of assets. As a result, 71 Base Building Energy certificates were removed from the dataset. In total, the cleaned dataset contains 3,661 unique

Base Building Energy certificates. The certificates are then organised in issue sequence for each individual asset in the database based on ascending NABERS identification numbers. Table 3.1 shows there are 1,153 unique assets in the energy dataset, with 818 having been certified multiple times.

Table 3.1. Number of unique assets in the energy dataset by number of certificates obtained.

Number of Certificates	Number of Unique Assets
1	335
2	242
3	192
4	106
5	72
6	75
7	63
8	37
9	20
10	9
11	2
All	1,153

3.1.1 Energy Performance Data

In order to ensure valid comparisons, energy performance in this study is measured using the raw consumption data input into each performance rating. Looking at Figure 3.1, "Energy Intensity", commonly abbreviated EUI for Energy Use Intensity, is intended to measure raw consumption. This metric is not altered by the decision to purchase Green Power offsets and has been consistently reported on every certificate; hence EUI is the logical choice for a comparative variable representing asset performance. Star ratings are associated with the benchmark factor, calibrated separately for each Australian city and thus unsuitable for comparison across regions. One must also assume that star ratings are unsuitable for comparison across time because it is unclear whether the undisclosed method for calculating a benchmark factor has changed over the 14-year life of the scheme.

Despite greenhouse gas mitigation being a key objective for investment in operational building energy efficiency, greenhouse gas emission figures from NABERS Energy certificates are not used. Early NABERS Energy certificates only report emissions that take Green Power offsets into account, leading to a number of "zero-emission" buildings. Second, early certificates exclusively use greenhouse gas accounting scopes one, two, and three (World Resources Institute and World Business Council for Sustainable Development, 2004), while later certificates switch between different accounting protocols. The presence of multiple accounting protocols leads to the discard of many valid certificates in an attempt to compare data only within the same accounting framework.[3] Lastly, greenhouse gas accounting practice has been very dynamic over 14 years; even if accounting scopes were consistent, conversion factors between the raw data and greenhouse gas emissions are sure to have varied over time. Thus, it would be difficult to differentiate trends in greenhouse gas emissions between operational management and changes in accounting practice. Instead, using EUI, a metric associated with operational greenhouse gas management but unrelated to its accounting, is the logical choice.

A potential concern in the use of EUI to interpret greenhouse gas performance is that it limits the scope of greenhouse gas mitigation to operational energy efficiency investment. Owners wishing to improve NABERS Energy ratings have three options: invest in on-site operational energy efficiency, purchase Green Power offsets, or switch fuel sources to maintain energy consumption intensity while reducing source greenhouse gas emissions.

While this research is limited to measuring the first option directly, it will take into account the decision to purchase Green Power. All building owners electing to purchase over 1% of their electricity via the Green Power scheme in every NABERS re-certification are identified using a binary variable. Theory on the effects of offsets in environmental markets is mixed. While the intent of offsets is to optimise the costs of mitigating a public bad (Kotchen, 2009), Gans and Groves (2012) describe how offsets can substitute for mitigation, potentially increasing production of the public bad. While this thesis does not intend to make a significant contribution to greenhouse gas emission offset theory, it is possible to answer empirically whether regular consumers of Green Power use offsets as a complement to mitigation – meaning owners initially invest in on-site mitigation and turn to offsets once the net costs of on-site mitigation rise above the cost of offsets – or as a substitute to mitigation – i.e. owners purchase offsets in lieu of on-site mitigation. The BEED Act requires that buildings disclose NABERS Energy ratings without accounting for Green Power offsets, so one can expect offsets and on-site efficiency to be valued differently, with a premium on the latter.

The third strategy for owners interested in mitigating greenhouse gas emissions, switching fuel sources, appears to be rarely used in practice. The correlation from first to final certification of the ratio of greenhouse gases per unit of energy is above 0.9 in buildings that can be compared over time, which most likely reflects minor variance in accounting factors from year-to-year.

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[3] To convert between different accounting protocols involves obtaining the specific amounts of fuels consumed in the building as well as conversion factors between those fuels and greenhouse gas emissions at the time of consumption. Neither is publicly available, hence one can only compare greenhouse gas emissions from identical accounting frameworks.

3.1.2 Green Owners

The disclosure of ownership details on each NABERS certificate enables the identification of "green owners", which will be defined as owners that are explicitly differentiating their assets as green or sustainable in the property market. In the establishment of the Global Real Estate Sustainability Benchmark, Bauer *et al.* (2011) rated three Australian-based institutional owners – Stockland, GPT and the Commonwealth Property Office Fund – as three of the top five "Global Environmental Leaders" for publicly listed property companies. In addition, GPT and a fourth Australian-based direct property ownership company, Investa, were identified as the top two Global Environmental Leaders for private property holding companies. Australian property investors are also listed on other sustainability indices, such as the Dow Jones Sustainability Index Australia, but these indices are restricted to listed firms, while the Global Real Estate Sustainability Benchmark is most specific to property funds and includes both listed and unlisted firms.

While the Global Real Estate Sustainability Benchmark study provided a systematic approach to classifying owners, there is also anecdotal evidence that these four Australian owners have invested in resource efficiency since the introduction of NABERS. For example, the 2011 Annual Report from the Investa-managed ING Property Fund (Investa, 2011), shows that planned investment is inversely related to a NABERS Energy rating (see Figure P.1 in the Preface).

In this thesis, assets owned by the four Australian companies identified as Global Environmental Leaders by Bauer *et al.* (2011) – Stockland, GPT, Commonwealth Property Office Fund, and Investa – are identified using a binary variable indicating green ownership. One non-listed property investment company – Local Government Super, the firm featured in the introduction of this thesis – is also identified as a Green Owner due to their responsible investment strategy (Churchill *et al.*, 2011). None of the foreign-based owners identified as Global Environmental Leaders from outside Australia were identified as holding NABERS-rated assets in Australia.

3.1.3 Location

The process of assigning NABERS certificates to an individual asset makes it possible to generate variables based on the location of the asset. In particular, Australian four-digit postcodes convey two useful pieces of data. One is the state or territory each asset is located in. This is important because Australia has three distinct levels of government – federal, state and local – and certain states, including New South Wales, the Australian Capital Territory, and Victoria, were the earliest adopters of NABERS Energy. The New South Wales government continues to manage the NABERS certification process throughout Australia. Hence, the particular state location of an asset can proxy fixed state government effects that may influence the decision to invest in operational resource efficiency.

The second useful variable that can be generated from a postcode is whether or not an asset is located in a capital city central business district (CBD). Office markets in a CBD offer prospective tenants greater choice than smaller provincial or suburban centres. Greater competition between owners may lead to greater investment in resource efficiency in major cities as part of an asset positioning strategy. Postcodes are used to identify buildings located in each capital city CBD: 800 for Darwin, 2000 for Sydney, 2601 for Canberra, 3000 for Melbourne, 4000 for Brisbane, 5000 for Adelaide, 6000 for Perth and 7000 for Hobart.

3.1.4 Asset Size and Hours of Use

The locational variables described above may be limited in regard to clear interpretation. In particular, significance of the capital city variable – particularly when interacted with the state variable – could relate to a wide scope of fixed location effects, such as property market cycles, local laws, cultural variations, operating hours, or building size. Kok et al. (2012a) found that when attempting to explain the diffusion of energy efficient office assets in the United States at a particular point in time, lagged economic variables describing income, employment and property market conditions were highly correlated. Lacking enough NABERS observations in each market to control for differences in economic drivers of energy efficiency across 14 years of NABERS certification, this study leaves the state and capital city variables to proxy average economic variation. But it is possible to produce truncated datasets with two variables from external sources that may influence energy efficiency potential: asset size and hours of operation. For example, Scofield (2009) argues that smaller buildings account for a disproportionate share of energy-efficient buildings by asset count in the United States.

Three external sources are consulted to procure the net lettable area (NLA) of each multi-certified asset. First, BEED Act certificates contain data on the area of each individual tenancy in the building. If the scope of a BEED Act certificate is for an "entire building" (as opposed to "part building"), the sum of all tenancy areas is assumed to equal total asset NLA. For assets lacking an entire building BEED Act certificate, each NABERS certificate publishes the name of the owner, so websites of individual building owners were consulted for published information that included the NLA of their assets. Third, sales records published in biannual research reports from Colliers International in each major metropolitan area of Australia also report NLA of assets sold in that six month period. If NLA could not be determined from either of the two methods above, the NLA on these sales records was used.

When a choice was presented, only office NLA was calculated in mixed-use buildings. Note that to be eligible for NABERS Energy certification as an office building, the asset NLA must be 75% office space or greater, so the possible inclusion of small retail areas is not likely to influence the results. In total, asset NLA was obtained for 806 of the 818 multi-certified assets in the energy dataset.

Data on intensity of asset use is only available from BEED Act certificates. The measure of occupancy provided on the certificate is the value of “Rated Hours”, measured in hours per week, collected during the NABERS performance audit and used in the calculation of the NABERS benchmark factor. This figure represents the number of hours per week the building is “safe, lit, and comfortable for office work” (Department of Environment Climate Change and Water NSW, 2010). It is a useful measure of how intense the asset is used. One can expect assets with higher operating hours to consume more energy.

With a BEED Act certificate being the lone source of Rated Hours data, only 696 of 818 multi-certified assets have at least one valid observation. Because Rated Hours can change in response to operational management decisions, there were 20 assets with multiple BEED Act certificates reporting at least a 4 hour difference in Rated Hours over time. In these cases, as well as those with minor differences, an average value across all certificates with known Rated Hours was chosen to represent all certificates obtained for that asset.

3.1.5 Sydney Subsample

As a result of the data gathering process described further in Chapter 5, additional exogenous variables are available for office buildings in central Sydney. In total, 119 of the 818 multi-certified assets in the database fall within the boundaries of the central Sydney office market as defined by the Property Council of Australia (Figure 3.2). Although this is a small sample, the use of a single market eliminates unobserved fixed effects variability caused by cross-market aggregation and, in this case, enables the research to test the effect of additional exogenous variables potentially omitted from the larger sample.

The additional data available for the Sydney subsample includes asset age and service quality rating. Asset age is obtained from the RP Data Cityscope database, and is calculated as the age of the asset, in years, at the end of 2011. The subjective quality of an asset is assessed by the Property Council of Australia (2006b) and explained in Section 2.3.3. Grades of “Premium”, “A”,”B”, “C”, and “D” are used to advertise these quality rating assessments and obtained for this research from a variety of agency reports. Owing to a small sample of C-grade assets, B- and C-grade assets are combined as "secondary" assets. There are no D-grade assets in the sample.

Figure 3.2. Geographical boundaries of the central Sydney office market and its six submarkets. Source: Property Council of Australia.

3.2 Descriptive Statistics

Table 3.2 provides a descriptive overview of the entire energy dataset with analysis by number of certificates obtained. To ensure sufficient sample sizes for each cohort, the number of multiple certificates is capped at 8. This means that 31 assets with more than 8 energy certificates are not analysed beyond their eighth certificate[4]. Note that the aggregate column on the far right only

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[4] In other words, the eighth certificate is assumed to be the "final" or most recent certificate in assets that have obtained nine or ten NABERS Energy certificates.

includes multi-certified assets; the column of assets with only one NABERS Energy certification is excluded from the totals.

Table 3.2. Descriptive statistics of the energy dataset. Statistics are Mean (Standard Deviation) unless otherwise indicated. Totals exclude assets obtaining only one NABERS Energy certificate.

	Number of NABERS Energy certifications								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**Total Multi-Certified**
N	332	242	192	106	72	75	63	68	**818**
Initial EUI (MJ/m^2/yr.)	669 (516)	639 (337)	660 (401)	577 (228)	553 (182)	642 (189)	618 (186)	643 (140)	**627 (299)**
Initial Star Rating [A]	2.66 (1.61)	2.65 (1.56)	2.67 (1.56)	2.83 (1.48)	2.88 (1.35)	2.59 (1.13)	2.69 (1.20)	2.43 (1.10)	**2.68 (1.44)**
Final EUI (MJ/m^2/yr.)	n/a	597 (291)	600 (377)	470 (185)	436 (151)	436 (126)	421 (114)	440 (115)	**526 (273)**
Final Star Rating [A]	n/a	2.87 (1.60)	3.06 (1.61)	3.66 (1.22)	3.94 (0.91)	3.97 (0.97)	4.17 (0.71)	3.96 (0.75)	**3.40 (1.43)**
Change in EUI* (MJ/m^2/yr.)	n/a	-42 (220)	-60 (221)	-107 (173)	-117 (180)	-207 (188)	-197 (177)	-203 (132)	**-102 (209)**
Net Lettable Area (m^2)	6,983 [D] (5,696)	10,560 [E] (10,854)	14,097 [F] (12,976)	15,655 [G] (13,715)	16,309 (13,045)	20,757 (13,736)	19,523 (16,265)	23,595 (19,272)	**15,310 [H] (14,081)**
% Purchasing Green Power [B]	n/a	6.6%	8.3%	12.2%	13.9%	34.7%	14.3%	16.1%	**12.3%**
% in CBD	38.2%	40.5%	48.4%	53.8%	45.8%	64.0%	61.9%	72.1%	**51.0%**
% with Green Owner [C]	0.0%	7.4%	7.8%	16.0%	22.2%	28.0%	46.0%	54.4%	**18.7%**
Avg. Days between Cert.	n/a	599 (483)	509 (272)	467 (219)	501 (180)	493 (144)	450 (79)	441 (99)	**518 (319)**
Median Days between Cert.	n/a	420	407	389	432	454	433	407	**418**
Median Year of 1st Cert.	2011	2011	2010	2009	2008	2006	2006	2004	**2009**

[A] Star ratings exclude Green Power offsets.

[B] Binary variable for an asset offsetting at least 1% of its energy through the Green Power scheme in every re-certification.

[C] Binary variable equalling 1 for an asset owned by Stockland, GPT, Commonwealth Property, or Investa.

[D] N=84 [E] N=235 [F] N=189 [G] N=104 [H] N=806

* Change in EUI is the difference between a particular re-certification and the initial benchmark certification.

The subsample of buildings that have an observed net lettable area (NLA) as described in section 3.1.4 is very similar to the entire dataset (only 12 observations are missing), so a description of the NLA data is provided in Table 3.2. However, there is a loss of 122 observations when the metric of Rated Hours is included. Table 3.3 presents the same descriptive statistics as Table 3.2, but for the subsample of 696 asset observations that include Rated Hours. Observations with one NABERS Energy certification are excluded because Rated Hours data was only collected for 15 of 332 assets and these single-certificate observations are not part of any investigation associated with Rated Hours data. The only notable difference between Tables 3.2 and 3.3 is a consistent increase in average asset size, which is to be expected because small assets are not required to obtain the BEED Act certificate that is the sole source of Rated Hours data.

Both tables of descriptive statistics suggest that participation in NABERS Energy is associated with a measurable improvement in asset energy efficiency on average. Mean energy consumption indicators decrease between a building's initial certification and its final certification. Energy consumption variance also decreases from initial certification to final certification. The key variable of interest, change in consumption, shows a clear trend of increasing energy savings over time and a decrease in variance. Boxplots in Figure 3.3 demonstrate the reduction in energy consumption and variance, particularly the reduction of outliers, as the number of certifications increase. These boxplots also suggest that after five certifications, mean energy consumption begins to stabilise while variance continues to decrease. Methods to test the robustness of this trend will be presented later in this chapter.

Table 3.3. Descriptive statistics for all asset observations that include data on Rated Hours (N=696). Statistics are Mean (Standard Deviation) unless otherwise indicated.

	Number of NABERS Energy certifications							
	2	**3**	**4**	**5**	**6**	**7**	**8**	**Total Multi-Certified**
N	179	161	88	69	71	61	67	**696**
Initial EUI (MJ/m^2/yr.)	661 (354)	687 (421)	595 (235)	556 (184)	640 (191)	617 (183)	644 (141)	**641 (305)**
Initial Star Rating [A]	2.65 (1.53)	2.51 (1.56)	2.72 (1.53)	2.84 (1.37)	2.64 (1.11)	2.69 (1.21)	2.45 (1.10)	**2.63 (1.42)**
Final EUI (MJ/m^2/yr.)	608 (287)	622 (399)	483 (193)	442 (151)	437 (124)	420 (116)	440 (116)	**529 (276)**
Final Star Rating [A]	2.87 (1.56)	2.94 (1.63)	3.61 (1.29)	3.92 (0.92)	3.98 (0.97)	4.17 (0.72)	3.98 (0.75)	**3.42 (1.41)**
Change in EUI* (MJ/m^2/yr.)	-53 (231)	-65 (235)	-112 (185)	-115 (183)	-203 (191)	-198 (174)	-204 (132)	**-112 (214)**
Net Lettable Area (m^2)	10,980 (11,741)	14.389 (12,929)	15,752 (13,130)	16,820 (13,030)	22,476 (13,453)	23,318 (17,385)	25,240 (19,515)	**16,578 (14,715)**
% Purchasing Green Power [B]	5.0%	8.7%	12.5%	14.5%	35.2%	13.1%	16.4%	**12.6%**
% in CBD	38.0%	48.4%	48.9%	46.4%	63.4%	63.9%	71.6%	**50.7%**
% with Green Owner [C]	9.5%	6.8%	15.9%	21.7%	26.8%	47.5%	53.7%	**20.3%**
Avg. Days between Cert.	569 (482)	478 (237)	463 (219)	501 (181)	494 (147)	447 (78)	441 (99)	**497 (296)**
Median Days between Cert.	399	398	380	433	449	432	407	**411**
Median Year of 1st Cert.	2011	2010	2010	2008	2006	2006	2004	**2010**

[A] Star ratings exclude Green Power offsets.

[B] Binary variable for an asset offsetting at least 1% of its energy through the Green Power scheme in every re-certification.

[C] Binary variable equalling 1 for an asset owned by Stockland, GPT, Commonwealth Property, or Investa.

* Change in EUI is the difference between a particular re-certification and the initial benchmark certification.

Besides change in consumption, three variables are also associated with the number of certifications. As would be expected, the number of certificates earned is related to the year a building first sought an assessment; early adopters are the only buildings with the highest numbers of certifications. Second, the percentage of assets managed by a green owner increases as the number of re-certifications increase. Unsurprisingly, this means green owners are likely to be early adopters of NABERS. Finally, there is a positive association between asset NLA, the percentage of assets in a CBD, and the number of certifications. This confirms the expectation that the CBD variable is correlated with asset size and also suggests that early adopters are more likely to own large assets. Figure 3.4 displays the fraction of large assets (greater than 20,000 m^2) commencing NABERS Energy certification in each quarter since its inception relative to small assets; the early adopters of NABERS clearly own a higher proportion of large assets relative to later adopters.

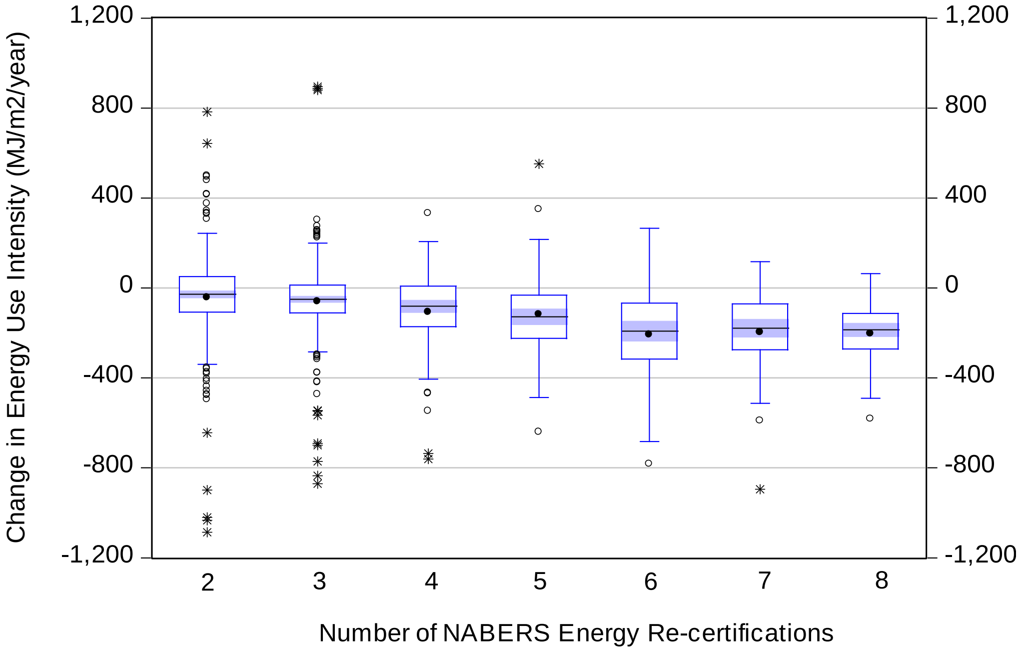

Figure 3.3. Boxplots of the relationship between number of certifications per asset and change in EUI between first and last certification. N=818.

Table 3.4 presents the correlation matrix between these related variables as measured in the dataset of all assets with observed NLA (N=806). The strongest correlation is between year of entry into NABERS and number of certificates. As described above, there are cross-correlations between green ownership, building size and the number of certificates. Green owners begin NABERS certification early and are likely to own large properties. Hence the interpretation of the green owner variable needs caution because it could be measuring green strategy as intended, or it could represent unmeasured characteristics of large institutional property owners, such as greater access to capital or the involvement of professional property managers.

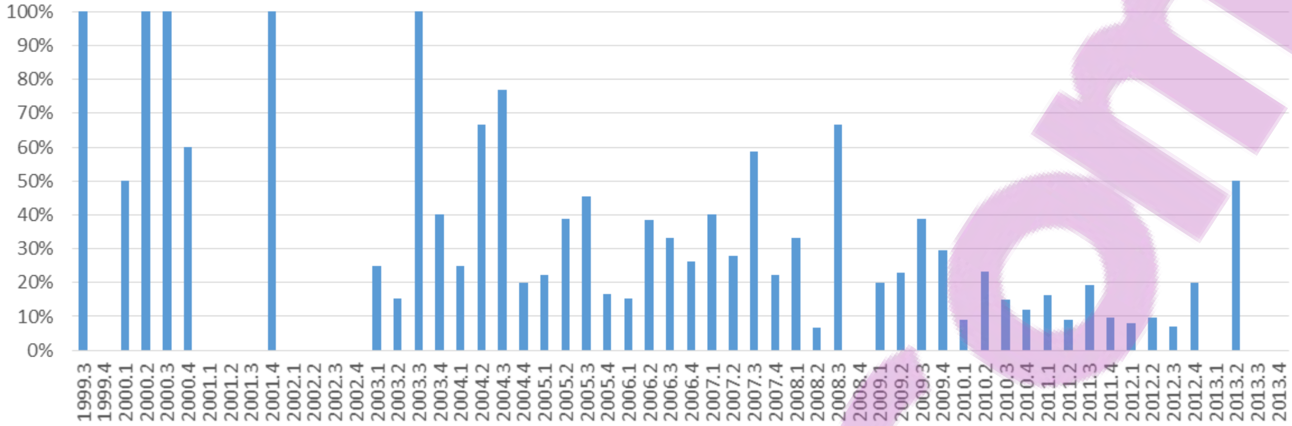

Figure 3.4. Proportion of large assets (>20,000 m^2) commencing NABERS Energy certification by quarter.

In this study, the number of certifications is the key variable of interest, so the exact interpretation of the green owner variable is not important. “Number of certification periods” estimates the degree of intervention in each asset as a result of NABERS certification. Of most concern is the strong negative correlation between year of entry into NABERS and number of certificates. Could “number of certificates” as a variable be measuring fixed time effects instead of the degree of intervention?

Table 3.4. Correlation matrix for selected variables. N=806.

	Change in EUI	Building NLA	Green Owner	Num. of Certs.	Located in CBD	Year of First Cert.	Initial EUI
Change in EUI	1.000						
Building NLA	-0.113*	1.000					
Green Owner	-0.134*	0.256*	1.000				
Num. of certificates	-0.298*	0.335*	0.380*	1.000			
Located in CBD	-0.109*	0.336*	0.115*	0.189*	1.000		
Year of first cert.	0.200*	-0.264*	-0.274*	-0.749*	-0.213*	1.000	
Initial EUI	-0.467*	-0.085*	-0.076*	-0.029	0.025	0.020	1.000

* *p*-value below 0.05

One time effect to consider is the “spillover effect” discussed by Borck and Coglianese (2009). Spillover effects represent benefits to non-adopters resulting from voluntary certification schemes. They are synonymous with what economists call a positive externality. Technology development is one example; voluntary adopters’ demand for energy efficient light bulbs creates a competitive supply market, bringing down the cost of production to the benefit of all lighting consumers. As a result, non-adopters could experience increased energy efficiency without having participated in a NABERS Energy audit.

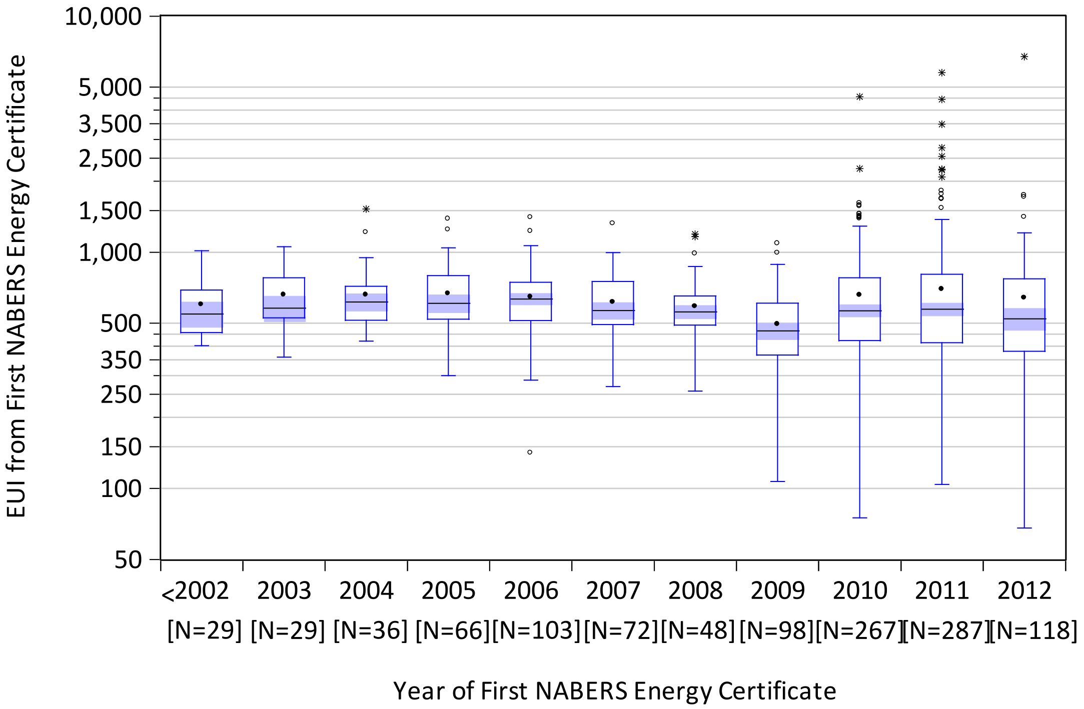

Figure 3.5. Distribution of initial EUI (MJ/m^2/yr.) based on year of entry into NABERS Energy certification. To account for a lognormal distribution, the EUI-axis has a logarithmic scale. The 2002 boxplot includes all entrants prior to 2002 and the 2012 boxplot includes entrants from early 2013.

To look for the presence of a spillover effect, Figure 3.5 plots the distribution of initial EUI as boxplots representing the year of an asset's first certificate. As NABERS Energy expands to cover all states there is a slight increasing trend in median and mean EUI between 1999 and 2006. Between 2007 and 2009 the trend changes direction, with initial EUI decreasing, suggesting the possibility that late voluntary adopters are benefiting from spillover effects prior to NABERS entry. In 2010, mean and median EUI abruptly rise along with an increase in highly inefficient assets appearing as outliers on the right tail. This change corresponds with the passage of the BEED Act and commencement of mandatory disclosure, suggesting this event is an important time effect in the database. While these outliers are responsible for the large jump in mean EUI, the line representing median EUI also increases in 2010. By 2012, spillover effects appear within the population of late mandatory adopters as mean and median EUI resume a decreasing trend. While this graphical analysis indicates spillover effects may be present, Table 3.4 reveals no statistically significant correlation between initial EUI and year of NABERS entry.

Figure 3.5 suggests time effects are not a concern, but one exception was noted – the introduction of mandatory NABERS Energy disclosure. To best control for this or any unexpected time effect, it will be useful to fix the number of certificates. Figure 3.6 demonstrates that if change in EUI is captured at every intermediate certification, central tendencies and variance follow a similar pattern as if change in EUI is only captured at the final certification (Figure 3.3). A full description of all variables at intermediate certification periods 2, 3 and 4 is included in Table 3.5. Periods 5 and higher are not included for two reasons. First, total sample size becomes too small for robust multivariate analysis across multiple markets. Second, assets with 5 or more certificates are all voluntary adopters, leaving no differentiation within the only expected time effect.

Table 3.5. Descriptive statistics of the energy dataset for all multi-certified observations at every intermediate certification period up to the fourth certificate. Statistics are Mean (Standard Deviation) unless otherwise indicated.

	s=2nd certificate	**s=3rd certificate**	**s=4th certificate**
N	818	576	382
Initial EUI (MJ/m^2/yr.)	627 (299)	623 (281)	604 (194)
Initial Star Rating [A]	2.68 (1.44)	2.69 (1.38)	2.70 (1.29)
EUI at Period s (MJ/m^2/yr.)	595 (297)	555 (165)	495 (165)
Star Rating at Period s [A]	2.93 (1.44)	3.18 (1.32)	3.53 (1.08)
Change in EUI at Period s (MJ/m^2/yr.)	-33 (187)	-67 (178)	-109 (164)
Net Lettable Area (m^2)	15,979 (14,363)[E]	18,187 (15,045)[F]	20,197 (15,607)[G]
% Purchasing Green Power [B]	12.3%	14.8%	18.0%
% in CBD	51.0%	55.4%	58.9%
% with Green Owner [C]	18.7%	23.4%	31.3%
Avg. Days between Certifications	518 (319)	564 (300)	531 (219)
Median Days between Certifications	448	448	467
Median Year of 1st Certification	2010	2008	2006

[A] Star ratings exclude Green Power offsets

[B] Binary variable for an asset offsetting at least 1% of its energy through the Green Power scheme in every re-certification

[C] Binary variable equalling 1 for an asset owned by Stockland, GPT, Commonwealth Property, or Investa

[D] N=84 [E] N=235 [F] N=571 [G] N=382

Although time between certificates is not uniform, it is typically more than a year. Looking at Table 3.2, the median number of days between certificates is usually around 400 days, indicating that most assets are recertified soon after an existing certificate expires. Nevertheless, it will be necessary to control for variation in the number of days between certifications because the average time between certification (μ=518 days) is much higher than the median, suggesting a number of assets with many years between certificates.

The decision not to allow Green Power offsets in mandatory disclosure has had an effect on the decision to purchase them. Systematic use of Green Power is seen in only 12.3% of multi-certified buildings. This adds support to the argument that operational energy efficiency is the most popular strategy employed by asset owners seeking to improve NABERS Energy ratings. As for the question of whether Green Power is used as a complement or substitute for operational efficiency, an observation that Green Power purchases are more popular with voluntary adopters suggests the former.

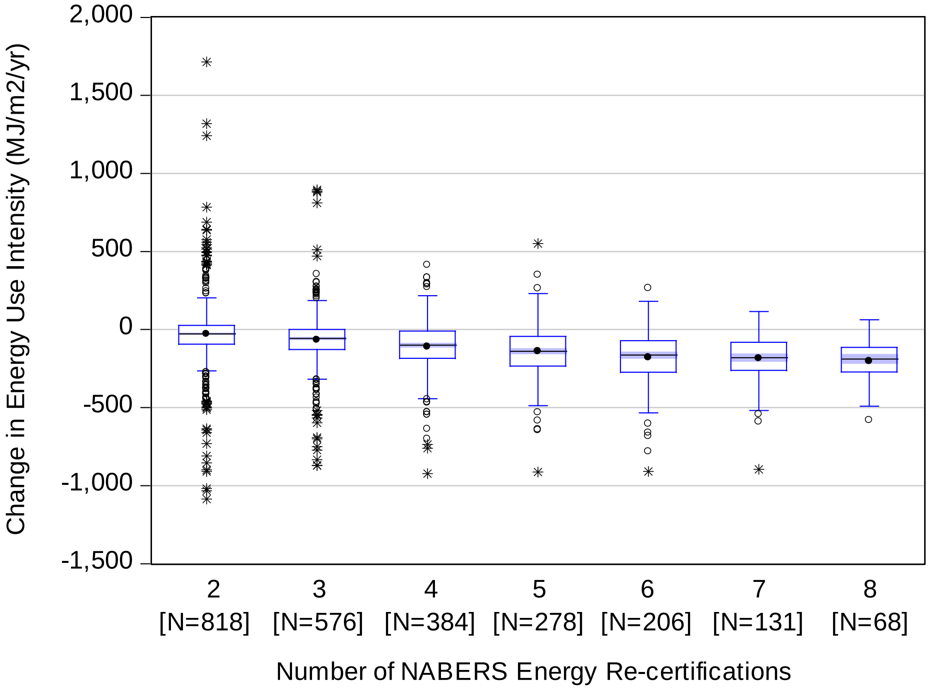

Figure 3.6. Boxplots of the relationship between number of certifications per asset and change in EUI at every intermediate re-certification.

Moving on to geographical distribution, Table 3.6 describes the dispersion of multi-certified assets by state. Figures on estimated total office NLA (Grosskopf, 2013) and white-collar employment in 2011 by state are also provided for context. According to the estimate of total office stock by NLA, just under half has been certified using NABERS Energy more than once. While this estimate is the most comprehensive attempt to measure the entire stock of office buildings in Australia, this data only covers capital cities and major suburban office parks, so it is likely an underestimate of the national stock. New South Wales and Victoria, the two states that pioneered the development of NABERS, have the largest percentage of total assets multi-certified. On the other side, small markets of the Northern Territory and Tasmania appear to be under-represented in the energy dataset, with less than 20% multi-certified. One cause of this gap in the Northern Territory is the number of assets with an unknown NLA.

For the additional asset data available in Sydney, Table 3.7 describes this subsample of multi-certified buildings. Multi-certified assets in Sydney are larger, have a higher rate of ownership by green owners, entered NABERS certification earlier, and have higher EUI at the time of initial certification. As of the most recent certification, there is little difference in measured EUI between the population of Sydney assets and non-Sydney assets. Thus, because of their relative inefficiency at the beginning, Sydney CBD assets appear to have improved energy consumption more than the non-Sydney CBD population.

Table 3.6. Number of multi-certified observations by state.

	ACT	NSW	NT	QLD	SA	TAS	VIC	WA	Total
Number of Assets	73	344	12	121	38	7	153	70	**818**
Num. Assets with known NLA	72	342	7	121	36	6	153	69	**806**
Multi-NABERS certified NLA (x1000)	800	5,598	29	1,672	484	47	3,230	1,018	**12,878**
Total Office Stock * (NLA x1000)	2,719	9,551	211	4,084	1,581	384	5,496	2,227	**26,253**
White-collar employment (x1000) **	174	2,146	67	1,316	486	140	1,713	703	**6,745**

* Capital city CBD areas and large suburban office parks only. Source: Grosskopf (2013).
** Source: Australian Census 2011.

Table 3.7. Expanded descriptive statistics for assets in the Sydney CBD as compared with all assets not located in the Sydney CBD. Statistics are Mean (Standard Deviation) unless otherwise indicated. Multi-certified assets only.

	Sydney CBD Assets	All Other Assets
N	119	699
Initial EUI (MJ/m^2/yr.)	717 (225)	612 (307)
Initial Star Rating [A]	2.49 (1.28)	2.71 (1.46)
Final EUI (MJ/m^2/yr.)	518 (220)	527 (281)
Final Star Rating [A]	3.75 (1.15)	3.35 (1.46)
Change in EUI (MJ/m^2/yr.)	-207 (200)	-86 (207)
Net Lettable Area (m^2)	24,410 (17,220)	14,522 [D] (13,297)
% Purchasing Green Power [B]	17.6%	11.4%
% in CBD	100%	42.6%
% with Green Owner [C]	32.8%	16.3%
% in Premium Assets	10.9%	n/a
% in A-Grade Assets	54.6%	n/a
% in Secondary Grade Assets [E]	34.4%	n/a
Number of Certifications	5.5 (2.3)	3.8 (2.0)
Building Age in 2011 (years)	27.7 (16.4)	n/a
Rated Hours (hours/week)	54.2 (6.50)[F]	52.4 (7.78)[G]
Median Year of 1st Cert.	2007	2010

[A] Star ratings exclude Green Power offsets
[B] Binary variable for an asset offsetting at least 1% of its energy through the Green Power scheme in every re-certification
[C] Binary variable equalling 1 for an asset owned by Stockland, GPT, Commonwealth Property, or Investa
[D] N=687
[E] Secondary-grade is an aggregation of B- and C-Grade assets
[F] N=105 [G]N=591

Over half of multi-certified Sydney assets in the dataset are specified with A-grade quality services. A full list of what constitutes an A-grade asset is published by the Property Council of Australia (2006b), with an overview in Section 2.3.3. Some of the criteria may limit the potential for energy efficiency investment, such as a greater mechanical lift handling capacity and shorter lift waiting intervals than B- and C-grade assets. As for building age, there is not a great range in central Sydney; most buildings were built or underwent a comprehensive renovation around the time of a late 1980s boom in commercial property (Hendershott, 2000).

3.3 Methodology

The research question being explored in this chapter asks what effect recurring NABERS Energy certification has on the operational energy consumption of existing office building assets. Descriptive statistics presented above lead to a hypothesis that not only do assets improve energy efficiency once involved in NABERS certification, but that the improvement is an incremental function of the depth of participation, measured by the number of certificates obtained. This section outlines a series of statistical tests of that hypothesis as well as an approach to answering the follow-up question regarding the difference, if any, between voluntary and mandatory adopters.

To establish the efficacy of an intervention, it is necessary to establish a pre-intervention benchmark representing energy consumption prior to the influence of NABERS certification. As was noted earlier, the methodological consistency of NABERS certification audits is what makes comparison between assets valid over time, so there is only one logical choice for a benchmark: the initial certification.

There are two limitations to this approach. First, it necessitates the loss of 332 asset observations with only one certificate. Table 3.6 shows approximately 50% of the Australian market by floor area is observed in the population of multi-certified assets, meaning that the loss of an additional 332 observations likely has less impact on the results than the potential for bias to be introduced in any simulation of a benchmark. The most probable explanation for an asset to only have one certificate is that it recently entered the NABERS scheme; Table 3.4 showed that number of certificates is highly correlated with year of entry.

The second limitation is the potential for asset owners to be influenced by the introduction of NABERS Energy, but invest in improvements prior to obtaining their first certificate. This will be addressed in two ways. First, one can account for it qualitatively by arguing that an observed improvement in energy efficiency beyond the first certificate is a conservative estimate of the effect of NABERS Energy because it fails to account for any improvement immediately prior to the first certificate. Second, this section describes the construction of a multivariate model that controls for an expected lack of improvement in properties already performing at high levels of energy efficiency.

The next task is to establish whether these tests need a finite population correction (Cochran, 1977). Because nearly every NABERS Base Building Energy certificate is included in the dataset, the need for a correction depends on the target population. At one extreme, researchers interested in the population of buildings with multiple NABERS Base Building Energy certificates, can assume the means and coefficients in all models are effectively the true population means and relationships because nearly every member of the population was observed. In this case, standard errors and confidence intervals can be ignored because a finite population correction would practically eliminate the standard error. On the other hand, this study is interested in applying results to office buildings outside Australia. In this case, a finite population correction is not necessary because the sample is a trivial selection of the global office market. Instead, one may argue that this sample is biased; hence future comparative studies will be needed to better describe the unique characteristics of the relationship between Australian political economy, its commercial property markets, and energy efficiency drivers besides the intervention of NABERS Energy.

Of course, there is a middle ground. One who is interested in the application of these results to a population of all office buildings in Australia faces a potentially nontrivial but incomplete sample. The lack of a thorough quantification of the entire population of interest makes a finite population correction impossible to perform in this study. Table 3.4 presented the best estimate of the Australian commercial office market stock, suggesting that observed multi-certified assets with known NLA comprise approximately 50% of the total population by area. The total population figure only considers capital cities and major suburban office parks, so it is an underestimate in regard to total office floor space in Australia. There are a number of observations in the NABERS Energy dataset outside these boundaries. But if the population of interest is all office assets over 2,000 square metres – i.e. only those assets subject to mandatory disclosure under the BEED Act – it is a better estimate since large buildings tend to be in major commercial centres. The next barrier is that each observation in this study is not associated with a particular square metre of office space, but rather an individual asset. No data exists on the total number of office assets in Australia and it may be that the volume of smaller assets not observed is enough to make the observed population trivial as a fraction of the entire population by asset numbers. In the next chapter, which presents the estimation of these models, all results will include an uncorrected standard error that can be adjusted by anyone wishing to perform a finite population correction.

Using the benchmark of an initial certificate, the remainder of this section specifies the tests that explore the relationship between the depth of NABERS certification and energy performance. First, single-variable models test whether average energy consumption improvement is a function of the number of certificates issued. Next, a number of multivariate regressions are run to include other exogenous variables – such as location, capacity for improvement, and willingness to purchase Green Power offsets – in order to test the robustness of the univariate findings. Finally, the multivariate model is modified to address the potential for multicollinearity and to explore the second research contribution regarding the comparison between voluntary and mandatory adopters of NABERS Energy.

3.3.1 Test 1: Marginal effect on performance from each additional re-certification

The simplest model of asset re-certification assumes an initial assessment provides information that enables the owner to invest his capital in a more efficient manner and improve performance. The subsequent assessment can be used to measure the effect of that investment. Such a model is commonly referred to using the cliché, "if you measure it, you can manage it". Consider an asset, *j*, with energy performance P_{j_s} at period *s*. Using information gained when measuring P_{j_s}, an owner performs intervention z_{j_s}, which is a multiplier such that, for performance at period *s+1*:

$$P_{j_s} \times z_{j_s} = P_{j_{(s+1)}} \tag{3.2}$$

In the case of energy consumption, it is expected that owners wish to reduce consumption, so $0 < E(z_{j_s}) < 1$.

To test this expectation, two-sample *t*-tests are used to examine whether z_{j_s} over the entire dataset is significantly different than 1, making the null hypothesis $P_{j_s} = P_{j_{(s+1)}}$. Since the dataset contains multiple assets, the test is run on sample means. Using the cross-sectional data for each NABERS Energy certification from *s*=1 to *s*=8, the comparison is between μ_{P_s} and $\mu_{P_{(s+1)}}$, the average P_{j_s} and $P_{j_{(s+1)}}$ for *j*=1 to *K* where *K* is the total number of assets in the dataset having been certified at both periods *s* and *s*+1:

$$\mu_{P_s} = \frac{\sum_{j=1}^{K} P_{j_s}}{K} \tag{3.3}$$

In this study, period *s* is not a fixed unit of time, but refers to the sequence of certification, with this study only considering an asset's first eight certifications. The median time between each period is slightly more than one year (see Table 3.2). A two-sample *t*-test is performed with the calculated values of μ_{P_s} and $\mu_{P_{(s+1)}}$. If the null hypothesis can be rejected, the difference in means is $\hat{\mu}_{z_s}$ or an estimate of the average effect across all interventions z_{j_s}.

An assumption behind the use of *t*-tests is that the distribution is normal. Because energy is bounded by zero – no building in the dataset is a net producer of energy – the distribution of energy consumption for each panel has a long right tail, suggesting a lognormal distribution. Figure 3.7 is a quantile-quantile plot for EUI and the natural logarithm of EUI for *s*=1, the initial certificate of all multi-certified assets (N=818). If the distribution is normal, all points should appear on the straight line. With only a few outliers at the extreme ends of the distribution, the log-transformed value of EUI is the best representation of a normally distributed P_{j_s} so the log-transformed value will be used in all *t*-tests.

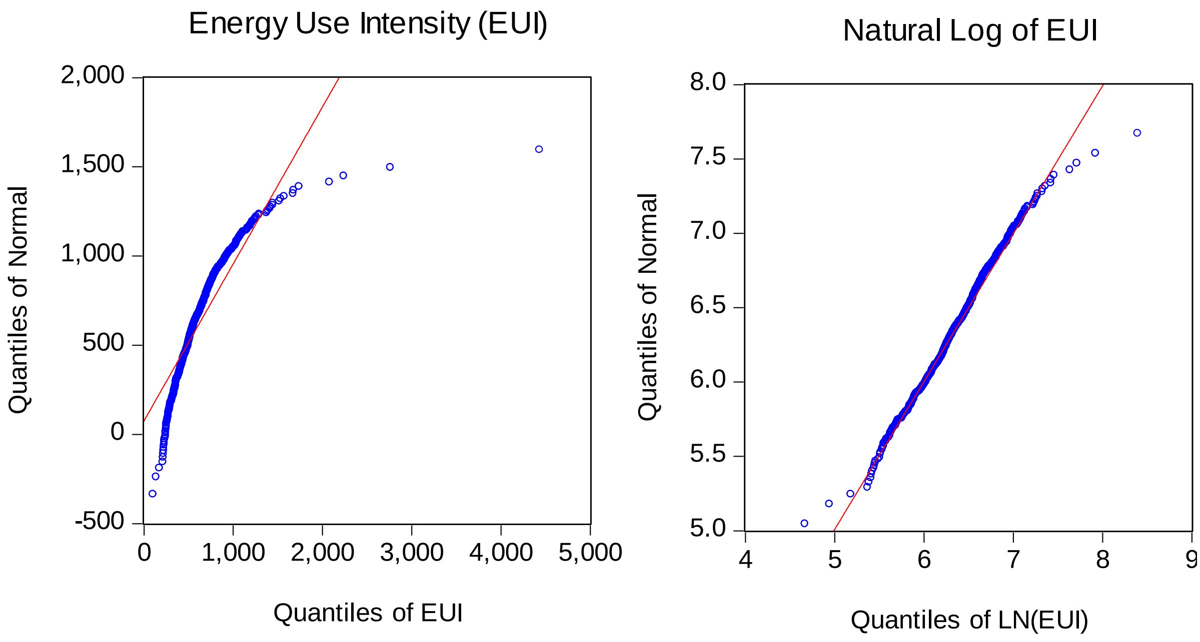

Figure 3.7. Quantile-quantile plots of EUI and the natural logarithm of EUI for the initial certificate (s=1) in all multi-certified assets (N=818).

3.3.2 Test 2: Cumulative effect on energy performance

One expects to see diminishing returns on performance improvement from additional re-certification. The previous test attempts to measure the path of a marginal intervention, comparing period *s* and period *s*+1. But different buildings may have taken different paths to improved performance; some buildings could have made rapid improvements while others chose steady improvements between certificates. Thus, understanding of the cumulative outcomes may be unreliable if only adjacent time periods are examined.

To investigate the cumulative outcomes of multiple certification as the number of certification periods increase, an additional six two sample *t*-tests are run on asset performance between the benchmark period s=1 and recertification periods s=3, 4, 5, 6, 7, and 8. Natural log-transformed performance is tested using the same method as described above, but with period steps that measure the outcome of interventions across multiple re-certification periods. If the market has a limit to how much it will intervene to improve performance, such a limit will be revealed if $\hat{\mu}_{z_s}$ trends asymptotically to a particular value as s increases.

3.3.3 Test 3: Multiple variables and the effect of an additional certificate

Tests 1 and 2 provide a more robust analysis than the descriptive statistics to the question of how multiple NABERS Energy certifications have influenced the energy efficiency of existing office assets. But the descriptive statistics revealed that depth of certification is slightly correlated with other variables such as green ownership, year of certification, and building size. To understand the relative influence of depth of certification, a multivariate model is constructed to explain observed improvements in energy consumption.

Consider asset j, in which EUI has been observed in the dataset from period s=1, the initial benchmark certificate, to period s=max, representing the “final”, or most recent, re-certification for asset j. Subtracting the energy consumption benchmark from the energy consumption of the most recent certification gives the total change in EUI, ΔP_j:

$$P_{j_{(s=max)}} - P_{j_{(s=1)}} = \Delta P_j \tag{3.4}$$

For the multivariate models, ΔP_j will be the dependent variable. In the t-tests, the dependent variable is P_{j_s}, with s varying based on the sequence being tested. To match the t-tests, $P_{j_{(s=max)}}$would be an obvious choice for the dependent variable in the multivariate model. In regard to the variable of interest – depth of involvement in NABERS Energy – the two approaches will give identical coefficients[5] because ΔP_j is a linear transformation of $P_{j_{(s=max)}}$. Rearranging Equations 3.2 and 3.4 and setting $(1 - 1/z_j) = b_j$:

$$P_{j_{s=1}} = \frac{P_{j_{s=max}}}{z_j} \quad \therefore \quad \Delta P_j = P_{j_{s=1}}\left(1 - \frac{1}{z_j}\right) = P_{j_{s=max}} b_j \tag{3.5}$$

But in regard to the overall model, the two approaches model slightly different outcomes. Modelling $P_{j_{s=max}}$ is less interesting than ΔP_j because $P_{j_{s=1}}$and $P_{j_{s=max}}$ are highly correlated (coefficient = 0.737), so while the overall explanatory power of the model will be high when $P_{j_{s=1}}$

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[5] See Appendix 1 for a demonstration of identical results regarding the variable of interest and the use of $P_{j_{(s=max)}}$ as the dependent variable.

is inserted as an independent variable, much of the explanation is due to the unsurprising correlation between initial and final energy consumption (see Appendix 1 for a demonstration). What is more interesting is how strongly one can explain the change in energy consumption using a variety of independent control variables in addition to the depth of NABERS Energy certification.

The multivariate model takes the form, for each asset *j*:

$$\Delta P_j = \alpha + \boldsymbol{\beta_1 LOC_j} + \boldsymbol{\beta_2 AST_j} + \beta_3 CAP_j + \boldsymbol{\beta_4 OWN_j} + \beta_5 AVGDAYS_j + \boldsymbol{\beta_6 CERT_j} + \epsilon_j \quad (3.6)$$

where the dependent variable, ΔP_j, is the change in resource consumption between the final and first certificate for each asset, α is an intercept, β is a coefficient, and ϵ represents stochastic error. These coefficients will be estimated with ordinary lease squares multivariate regression. Vector variables are indicated in bold type. Each independent variable or vector variable is explained in detail below, but to summarise:

$\boldsymbol{LOC_j}$= Fixed effects associated with the location of asset *j*
$\boldsymbol{AST_j}$= Fixed characteristics of asset *j* (i.e. size and hours of use)
CAP_j= Capacity for asset *j* to improve its energy performance
$\boldsymbol{OWN_j}$= Fixed characteristics associated with the owner of asset *j*
$AVGDAYS_j$= Average days between certificates for asset *j*
$\boldsymbol{CERT_j}$= Depth of participation by asset *j* in NABERS Energy (number of certificates)

A list of all variables contained within each independent vector variable is shown in Table 3.8. Note that the year of certification is not included in this model because of its high correlation with the variable of interest. The following section, 3.3.4, establishes a second multivariate model that fixes the number of certificates in order to test for the influence of fixed time effects on the variable of interest.

Figure 3.8 shows a histogram of the distribution of dependent variable ΔP_j and a quantile-quantile plot to examine the match between the probability distribution of ΔP_j and the standard normal distribution. It does not appear that a transformation of the dependent variable will be needed, although the kurtosis of the distribution is high (7.487), reflecting the high probability of little to no change in energy consumption along with long tails on both sides. Note that negative values of the dependent variable ΔP_j represent energy savings relative to the initial benchmark.

The independent variable of interest is depth of NABERS Energy participation, measured using a flexible functional form in the vector variable $\boldsymbol{CERT}$. Depth of participation is measured by proxy using the number of certificates obtained by each asset in the dataset excluding the initial benchmark certificate (i.e. the number of re-certifications for each asset). Since diminishing returns to performance outcomes are expected as the number of re-certification periods s increases, the vector variable includes a series of binary variables measuring depth of participation. If an asset has obtained s certificates, then it assumes a value of one for the s-certificate variable and zero for the remaining $\boldsymbol{CERT}$ variables. For example, an asset with five NABERS Energy certificates takes a value of one for the 5-certificate variable and zero for the 2-, 3-, 4-, 6-, 7-, and 8-certificate variables. Note that interpretation of this construction is similar to the second univariate model – the coefficient of each variable measures the cumulative influence of s certifications, not the marginal influence. The 2-certificate variable is omitted from all specifications as a reference category.

Table 3.8. Independent variables and their units as specified in Equation 3.6.

$\boldsymbol{LOC}$	$\boldsymbol{AST}$	CAP	$\boldsymbol{OWN}$	$AVGDAYS$	$\boldsymbol{CERT}$
State=ACT (reference)	Asset NLA (Nat. Log. m^2)	Initial EUI (MJ/m^2/yr.)	Green Power (1=yes)	Avg. days between certificates (Natural Log. days)	2 certificates (reference category)
State=NSW (1=yes)	Rated Hours (hrs/week)		Green Owner (1=yes)*Initial EUI		3 certificates (1=yes)
State=QLD (1=yes)	Premium Grade (1=yes) ^{A}				4 certificates (1=yes)
State=SA (1=yes)	A-Grade (reference) ^{A}				5 certificates (1=yes)
State=VIC (1=yes)	B- or C- Grade (1=yes) ^{A}				6 certificates (1=yes)
State=WA (1=yes)	Asset Age (yrs. in 2011)^A				7 certificates (1=yes)
State=Other (1=yes)					8 certificates (1=yes)
CBD=Canberra (1=yes)					
CBD=Sydney (1=yes)					
CBD=Brisbane (1=yes)					
CBD=Melbourne (1=yes)					
CBD=Adelaide (1=yes)					
CBD=Other (1=yes)					

^{A} Asset quality and asset age only available for the Sydney subsample.

The first independent control vector variable, $\boldsymbol{LOC}$, represents fixed effects metrics associated with location, including the binary variable for each Australian state or territory and the binary variable indicating whether a building is located in a capital city central business district (see section 3.1.3). The state variables test whether certain states are more likely to invest in energy efficiency or face stronger demand for energy efficiency. In the event of any significant differentiation, the state variables enable the model to control for an unobserved range of fixed effects specific to each state that may lie behind the differentiation, such as climactic zones, state policy, property market cycles and economic conditions. Because of small sample sizes in the Northern Territory and Tasmania, these states will be grouped as "Other". To improve the imperfect proxy of state boundaries to estimate these fixed effects, the capital city variable isolates intrastate market differentiation in an interaction with the state variable.

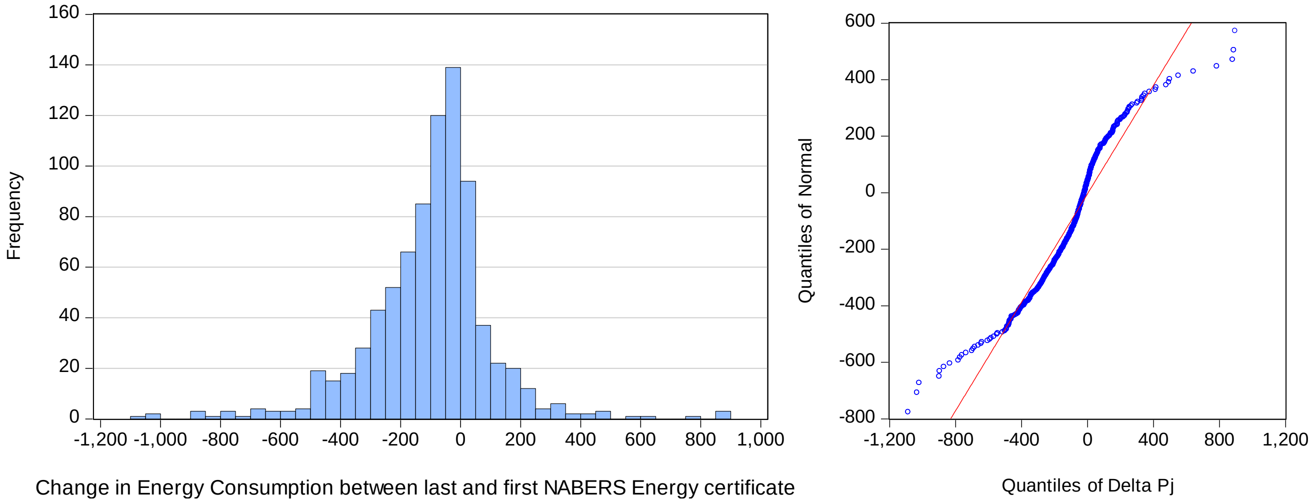

Figure 3.8. Histogram and quantile-quantile plot of the distribution of the dependent variable $\Delta\boldsymbol{P}_j$ (N=818).

The second vector variable, $\boldsymbol{AST}$, represents fixed characteristics of each asset. Because a physical address is the only asset characteristic consistently disclosed on a NABERS Energy certificate, data for this variable must be sourced externally (see Section 3.1.4). None of the external sources are available for the entire sample of 818 assets. Expanding this vector to include additional variables results in a reduced number of observations and multiple model specifications as follows:

Specification 1: N=818, No controls for asset characteristics ($\boldsymbol{AST}$ removed)
Specification 2: N=806, Asset NLA included.
Specification 3: N=696, Asset NLA and Rated Hours included.
Specification 4: N=119, Sydney only ($\boldsymbol{LOC}$ removed), Asset Quality, NLA and Age included.

Specification 2 excludes 12 asset NLA-missing observations and explicitly controls for asset size. Figure 3.9 shows that asset NLA, needs to be transformed in order to be normally distributed. With the exception of a few outliers at either end, the log-transformed value of NLA exhibits a standard normal distribution. This log-transformed value of NLA will be used in the model.

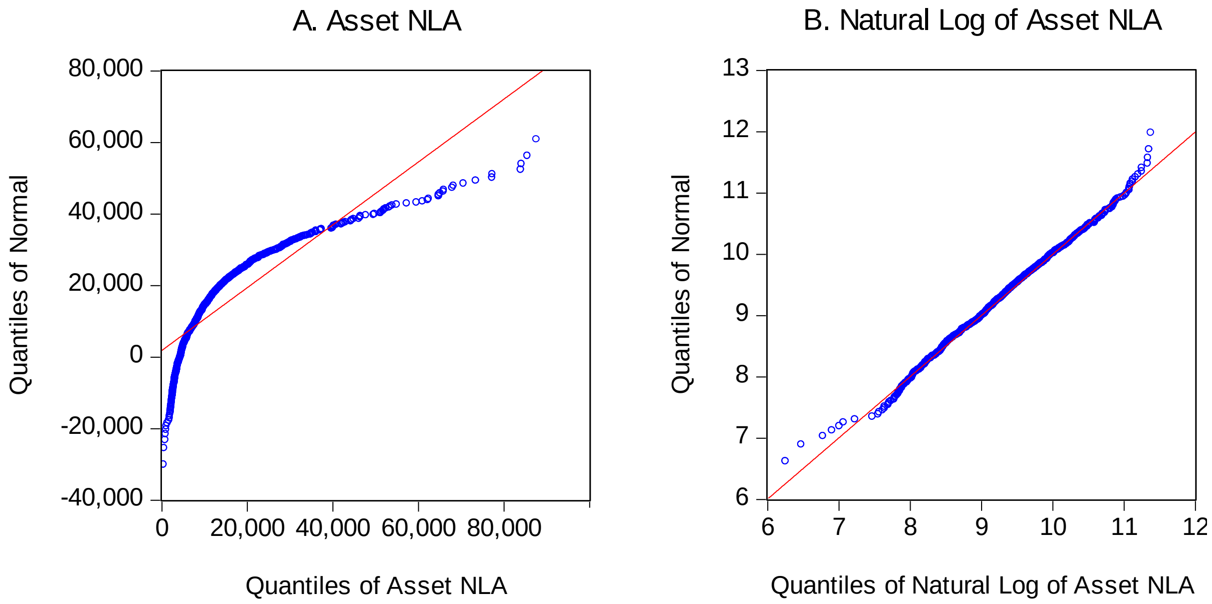

Figure 3.9. Quantile-quantile plots comparing the observed distribution of asset NLA against a theoretical normal distribution (N=806).

Next, specification 3 includes data on the intensity of use for each asset, measured using the NABERS metric of Rated Hours. This measurement, using a consistent methodology, is only available for assets that have obtained a BEED Act certificate. As a result, 110 observations must be removed from the known-NLA sample, meaning N=696 for any model that includes asset NLA and Rated Hours. No transformation is applied to Rated Hours data, implying an assumption of a linear relationship between energy efficiency and each hour per week the building is in operation. Figure 3.10 shows the distribution of Rated Hours, with a clear mode of 50 hours per week. The use of binary variable categories to represent Rated Hours in the model was considered but clear logic for any split in the data could not be determined, thus any attempt to segregate the data introduced the potential for unknown bias.

Specification 4 includes only the buildings in central Sydney, as described in section 3.1.5. This subsample eliminates any locational fixed effects, so ***LOC*** is removed from this model specification. Sydney's four commercial office submarkets – City Core, Midtown, Western Corridor, and Southern (see Figure 3.2) – were considered as a locational control but removed because local governance, climate, and economic trends are either identical or relatively similar.

Instead the rationale behind this specification is to test for the influence of asset quality and asset age on the potential for energy efficiency.

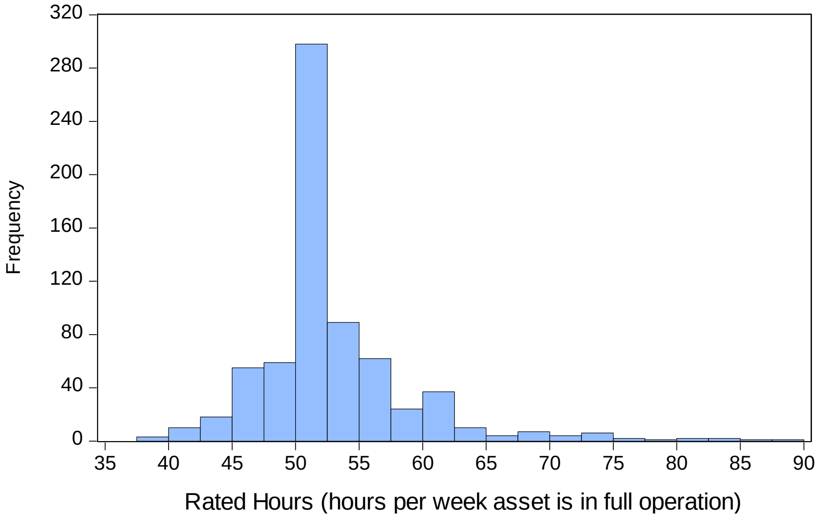

Figure 3.10. Histogram distribution of Rated Hours for all assets (N=696).

The capacity for improvement, CAP, is a critical control variable given the use of an initial certificate to benchmark energy performance. The best variable to estimate capacity to improve is this initial EUI benchmark ($P_{j_{s=1}}$). An alternative measure for capacity to improve, the star rating from the initial NABERS certificate, was considered but the continuous variable of initial EUI is better able to differentiate potential than the categorical measure of initial star ratings. All else being equal, assets with high initial EUI are expected to improve more than those with low initial EUI. Another reason to include this variable is to relax the assumption that an initial NABERS certificate is acceptable as a pre-intervention benchmark. Assets with low initial EUI are more likely to have invested in operational energy efficiency prior to certification, so including this variable allows the model to control for this.

Characteristics and decisions of the asset owner are included in the vector variable $\boldsymbol{OWN}$. One variable is the choice to purchase Green Power consistently, modelled as a binary variable indicating whether an asset has purchased Green Power in every NABERS Energy re-certification[6]. Since an owner has a choice as to whether he invests in operational efficiency, purchases Green Power offsets, or pursues both means of reducing greenhouse gas emissions, this variable will answer the question whether Green Power offsets are a substitute or complement to operational efficiency investment (see section 3.1.1). In the context of the BEED Act, it is expected that Green Power offsets are complements to operational efficiency since

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[6] Identification of a Green Power purchaser does not depend on the asset owner purchasing Green Power in the initial benchmark certification.

owners have an incentive to pursue the latter path first, leaving the former option attractive only for owners that see value in outcomes beyond operational best practice (such as carbon neutrality).

The green owner variable described in section 3.1.2 is also included in this vector. However, green ownership will be assessed as an interaction between the green owner binary variable and the variable for improvement capacity. The reason for this choice is that the binary variable on its own assumes all green owners start with identical asset potential for improvement as non-green owners. However, besides increased investment in energy efficiency of their existing assets, green owners may be more likely to develop or acquire assets that are already energy efficient. The interacted variable allows for a difference in asset energy improvement potential between green and non-green owners. It is best interpreted as the excess energy savings that a green owner will pursue beyond that which a normal owner would pursue after accounting for what both groups would pursue given an initial asset energy consumption benchmark. The alternate specification where green ownership is only included as a binary variable does not produce as good of a fit to the existing data as the interaction between green ownership and asset capacity for improvement.

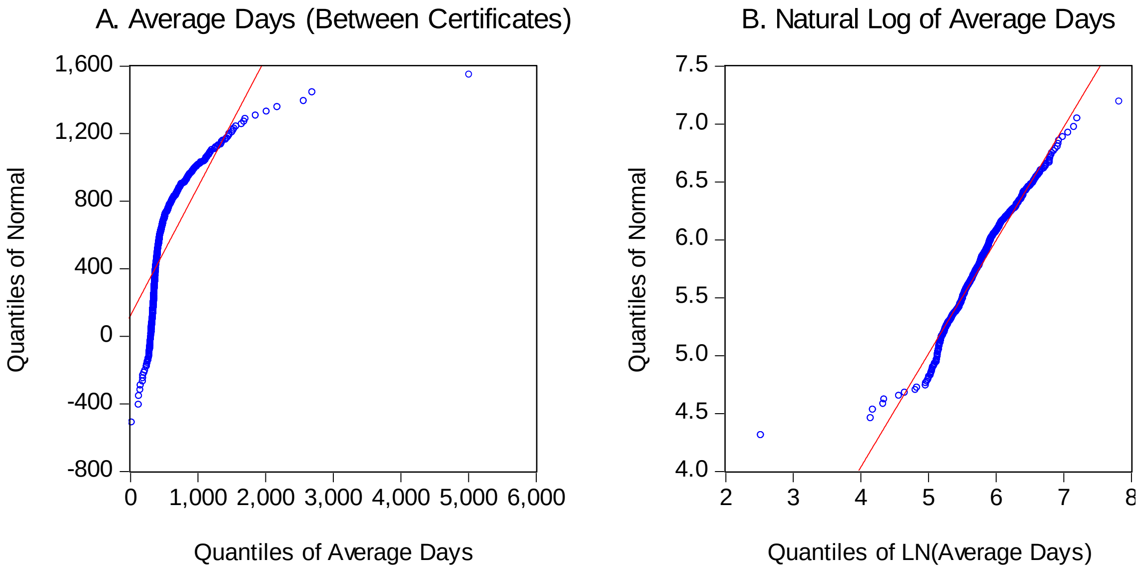

Figure 3.11. Quantile-quantile plots for the variable measuring average days and its natural log transformation.

The final control variable is $AVGDAYS$, which attempts to control for variance in time between periods for each asset. As is seen in the gap between median and mean days between certification in the descriptive statistics, there are a number of assets with lengthy times between certifications. Hence the *t*-tests, which assume each period represents an equal time for the owner to improve energy efficiency, can be improved by controlling for observed variations in this assumption. As can be seen in Figure 3.11, the number of assets with long times between certificates means a natural log transformation best approximates a normal distribution for the variable measuring average days between certificates.

3.3.4 Test 4: The influence of fixed time effects

High correlation between year of the benchmark NABERS Energy certificate and the number of total NABERS Energy certificates obtained by each asset means that year of entry cannot be controlled for in the model described in the previous section, where number of re-certifications is the variable of interest. Instead, to estimate the influence of fixed time effects within the coefficient of the variable measuring the number of re-certifications, three additional models will be run that fix the number of certificates earned. Variables representing fixed time effects become the variables of interest in these models. Two approaches to measuring time effects are considered in four separate specifications for each model: the particular year an asset obtained its benchmark NABERS Energy certificate and three definitions of mandatory and voluntary adopters.

Models with the number of re-certifications fixed are constructed using a similar approach as described in the previous section, with ΔP_j as the dependent variable. However, instead of measuring ΔP_j using $P_{j_{(s=max)}}$ for each asset j in Equation 3.4 these models will measure ΔP_j at a fixed period u of NABERS Energy certification:

$$P_{j_{(s=u)}} - P_{j_{(s=1)}} = \Delta P_{j_{(s=u)}} \text{ for } u = 2,3,4 \tag{3.7}$$

As described in Equation 3.7, the three models that will be constructed test for the influence of fixed time effects as of the second, third, and fourth certificate obtained for each asset respectively. Additional models are not run for the fifth through eighth certificates because there are no assets that meet the definition of a mandatory adopter, one of the time effects of interest.

Each model investigating fixed time effects follows the general specification similar to Equation 3.6:

$$\Delta P_{j_{(s=u)}} = \alpha + \boldsymbol{\beta_1 LOC_j} + \beta_2 AST_j + \beta_3 CAP_j + \boldsymbol{\beta_4 OWN_j} + \boldsymbol{\beta_5 TIME_j} + \epsilon_j \tag{3.8}$$

The control variables $\boldsymbol{LOC}$, AST, CAP, and $\boldsymbol{OWN}$ are identical to those in Equation 3.6, but with two exceptions. First, when u=4, the model estimating determinants of energy efficiency as of the fourth NABERS Energy certificate, there are no observations in Tasmania, Northern Territory or outside the CBD of Adelaide in South Australia. As a result, state and CBD variables for "Other" (the combination of Northern Territory and Tasmania), along with the CBD variable for Adelaide, are removed from $\boldsymbol{LOC}$ in the fourth-certificate model. Second, the only representation of AST used in is the second specification from the last model, where asset NLA is included as a control variable. Other than the dependent variable, the differences between this model and Equation 3.6 are the elimination of $\boldsymbol{CERT}$, which is now constant in each model, and the replacement of $AVGDAYS$ with a vector variable $\boldsymbol{TIME}$. Ordinary least squares regression will again be used to estimate the intercept, coefficients and stochastic error.

The number of observations in each of these fixed-certificate models is the sum of all assets obtaining u or above certificates that have observed asset NLA. For the two-certificate model, N=806 (all multi-certified assets with observed asset NLA). For the three-certificate model, N=571 (assets with only two certificates have been removed), and the four-certificate model further removes assets with only three certificates, so N=386.

Table 3.9 lists the variables included in the new vector variable, $\boldsymbol{TIME}$. The vector includes the variable representing the average number of days between certificates and one of four possible measures of fixed time effects. The variable representing the average number of days between certificates now measures the average number of days between certificates from the initial benchmark to the certificate issued in period u (the fixed re-certification period used to calculate the dependent variable in each model). In addition, binary variables are included that represent one of the time effects of interest: the year of the initial benchmark certificate or whether the asset is classified as a mandatory adopter. Later on in this section, three separate definitions of mandatory adopter will be developed, so there are four specifications in each of the three models:

Specification A: Binary variables representing year of initial certification
Specification B: Binary variable representing a mandatory adopter (conservative definition)
Specification C: Binary variable representing a mandatory adopter (moderate definition)
Specification D: Binary variable representing a mandatory adopter (liberal definition)

For the year of initial certification, a small number of benchmark observations in 2002 and earlier mean that the variable for 2003 includes all 1999 through 2002 start dates. At the other end, each model groups the final two years together because of a low number of observations in the final year. For example, two observations in 2013 are grouped with 2012 in the model investigating performance as of the second certificate. The variable representing the earliest adopting assets commencing certification between 1999 and 2003 is excluded from the model as the reference time effect.

Table 3.9. Variables included in $\boldsymbol{TIME}$ for Equation 3.7, the model where number of certificates is fixed

$\boldsymbol{TIME}$
Avg. days between certs. (Natural Log. days)
Start 1999-2003 (reference)[A] Start 2004 (1=yes) [A] Start 2005 (1=yes) [A] Start 2006 (1=yes) [A] Start 2007 (1=yes) [A] Start 2008 (1=yes) [A] Start 2009 (1=yes) [A] Start 2010 (1=yes) [A,C] Start 2011 (1=yes) [A,C] Start 2012-2013 (1=yes) [A,C]
Mandatory Adopter (1=yes)[B] Voluntary Adopter (reference)[B]

[A] Only included in Specification A.

[B] Excluded from Specification A

[C] Groups for recent years change in the models investigating performance at the third and fourth certificates. In the third-certificate model, 2011 and 2012 are combined; no assets commence in 2013. In the four certificate model, 2010 and 2011 are combined; no assets commence in 2012.

Separating voluntary adopters from mandatory adopters is not straightforward. While there is a date for passing of the BEED Act (28 June 2010) and a date disclosure obligations commenced (1 November 2010), discussions on the legislation began in 2008. Figure 3.12 shows the time distribution of when each asset in the two-certificate model obtained an initial NABERS Energy benchmark certificate. There are two distinct peaks in activity – Q1 2006 and Q4 2010. The first peak is correlated with the positioning of a number of Australian property funds as green and sustainable (Bauer *et al.*, 2011). These are voluntary adopters motivated by competitive strategy to position their portfolio in the market. The second peak neatly corresponds to the commencement of mandatory disclosure obligations.

This study will test three separation points in alternate specifications of Equation 3.8 as indicated above. The conservative approach defines mandatory adopters as any building obtaining its first NABERS Energy certificate on or after the commencement of disclosure obligations on 1 November 2010. But as Figure 1 demonstrates, there is clear growth in participation prior to mandatory disclosure enforcement; hence the conservative approach likely omits buildings motivated by anticipation of mandatory disclosure. But where is a more liberal break in the data to be placed? The drop in voluntary certification in late 2008 is likely due to the global financial crisis, but it does provide a notable separation between peaks. Thus, the liberal definition assumes all certification entrants from Q1 2009 were motivated by upcoming mandatory disclosure legislation. To test the sensitivity of these two extremes, a moderate definition of mandatory disclosure participants identifies those entering certification in or after Q1 2010.

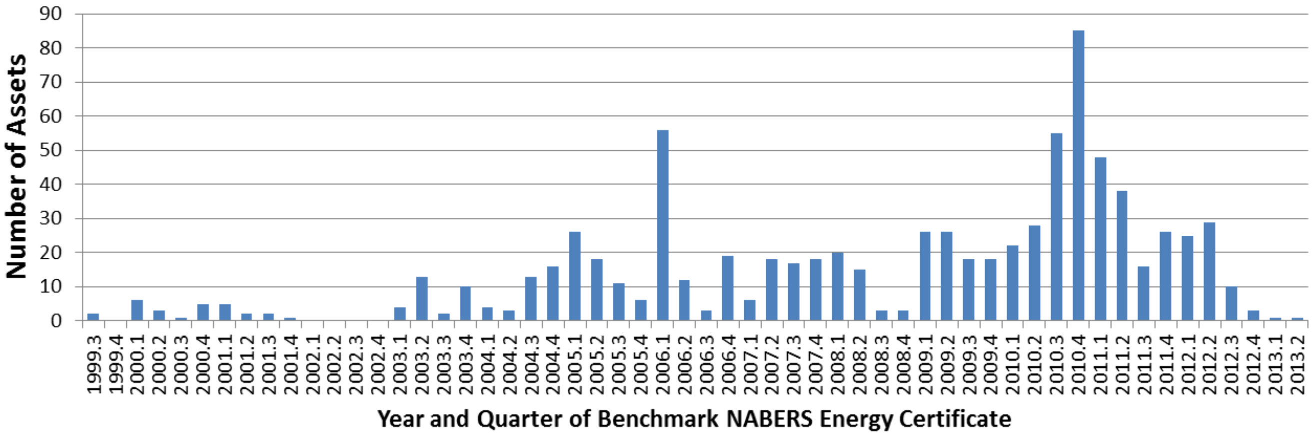

Figure 3.12. Histogram of the year and quarter each multi-certified asset received its NABERS Energy benchmark certificate. N=818.

In the four-certificate model, only nine of 382 assets with four certificates meet the conservative definition of a mandatory adopter. These nine assets share other characteristics besides their classification as mandatory adopters; most notably, they obtain a new NABERS Energy certificate approximately every six months, as opposed to the typical time between certificates of 14-16 months. Thus owing to biased data on conservative mandatory adopters with four certificates, Specification B is not run in the four-certificate model.

3.4 Summary

This chapter outlined the construction of an extensive dataset of office asset energy consumption audits in Australia. These data are used to specify a comprehensive series of statistical tests to explore whether participation in an energy disclosure scheme is related to asset energy efficiency. One objective is to understand how the depth of participation in NABERS Energy is related to energy efficiency in existing commercial office buildings. The second objective is to assess whether mandatory adopters of NABERS Energy behave differently to voluntary adopters in regard to energy efficiency improvements over time.

The first two tests provide additional rigour to the descriptive statistics that suggest NABERS certification leads to increased energy efficiency and decreased variance among 818 multi-certified assets throughout Australia. Two-sample *t*-tests are first run on adjacent certification periods to see if the "treatment" of an additional NABERS Energy certificate reduces mean energy consumption. Second, an additional six two-sample *t*-tests are run across multiple certification periods to understand cumulative outcomes of investment in energy efficiency.

The third and fourth tests go beyond the assumption that NABERS Energy participation is the only variable affecting investment in energy efficiency. Fifteen multivariate regression models are constructed to isolate the influence of NABERS Energy participation while controlling for asset characteristics, location, owner characteristics, energy efficiency potential, fixed time effects and variation in time between re-certification periods. One of the fixed time effects is mandatory adoption, which is explored to understand the difference in energy efficiency outcomes between voluntary and mandatory adopters. Table 3.10 summarises the specification of each of the 15 model specifications.

Table 3.10. Summary of multivariate model specifications described in sections 3.3.3 and 3.3.4.

Model Equation	Specifications	N
3.6	1: No asset characteristics	818
	2: Asset NLA measures asset characteristics	806
	3: Asset NLA and Rated Hours measure asset characteristics	696
	4: Sydney only; Asset NLA, Age and Quality measure asset characteristics	119
3.8 (u=2nd cert.)	A: Time effect=Binary variables representing year of initial certification	806
	B: Time effect=Conservative definition of mandatory adopter	
	C: Time effect=Moderate definition of mandatory adopter	
	D: Time effect=Liberal definition of mandatory adopter	
3.8 (u=3rd cert.)	A: Time effect=Binary variables representing year of initial certification	571
	B: Time effect=Conservative definition of mandatory adopter	
	C: Time effect=Moderate definition of mandatory adopter	
	D: Time effect=Liberal definition of mandatory adopter	
3.8 (u=4th cert.)	A: Time effect=Binary variables representing year of initial certification	386
	B: Not run (insufficient observations of conservative mandatory adopters)	
	C: Time effect=Moderate definition of mandatory adopter	
	D: Time effect=Liberal definition of mandatory adopter	

Chapter 4

Environmental Effectiveness: Results and Conclusions

In the previous chapter, quantitative tests were developed to assess the effect of NABERS [National Australian Built Environment Rating System] Energy as an intervention to improve energy efficiency and reduce greenhouse gas emissions in existing Australian office assets. A further test was also described to establish whether the motivation to participate – voluntary or mandatory adoption – affects performance outcomes. This chapter presents the results from those four tests and discusses the implications for public policy.

Section 4.1 describes the results from each of the four tests developed in Chapter 3. Interpretations of these results are presented along with statistical tables. Conclusions regarding the key research questions – the effect of NABERS Energy audits on operational energy consumption and differences between voluntary and mandatory adopters – are presented in Section 4.2. Limitations of the model and an overall summary of the implications for policy regarding energy efficiency and greenhouse gas mitigation in existing buildings are presented at the end of this chapter.

Note that results in this chapter are not presented with finite population corrections because this research is interested in the potential for the sample to inform global policy and market interventions. The office assets studied are a trivial fraction of the global population. Instead, there is a potential for a biased sample, which is discussed near the end of this chapter. For anyone interested in narrower populations, such as an application to all office building assets in Australia, standard errors are provided to enable corrections.

4.1 Results

As was described in Chapter 3, the results for univariate models are presented first. Two sets of *t*-tests confirm the trend of increasing energy efficiency as a function of depth of participation in NABERS Energy that was observed in the descriptive statistics. Reductions in energy consumption increase for approximately five to six years after an initial benchmark certificate then begin to show the effect of diminishing returns as the market settles into an apparent post-certification equilibrium consumption intensity of approximately 430 MJ/m^2/year.

Multivariate models controlling for spatial location, asset characteristics, and owner characteristics also confirm the conclusions of the *t*-tests; depth of participation is associated with energy efficiency. Additional models looking for time effects find that there is no influence from the year of commencement on long-term energy savings. However, there is weak evidence that mandatory adopters undergo faster reductions in energy consumption relative to voluntary adopters, a finding that can be explained with the development of a market for energy efficiency retrofits from early voluntary adopters along with increased awareness of energy consumption in the national office market at the time mandatory disclosure policy was introduced.

4.1.1 Test 1: Marginal effect on performance from each additional re-certification

The first model examines the difference in mean energy consumption between two adjacent certification periods. Table 4.1 presents the results of seven *t*-tests run on mean energy consumption for the common sample of assets obtaining certificates in sequence *s* and *s*+1. Of interest is the average multiplier $\hat{\mu}_{z_s}$ that represents an estimated energy consumption multiplier from obtaining one more certificate after obtaining *s* NABERS Energy certificates. The hypothesis is that $\hat{\mu}_{z_s}$ is less than one for early certificates and then trends towards one as *s* increases.

Table 4.1. Results describing the marginal effect on performance from each additional re-certification.

Sequence *s* to *s*+1	Mean ln(P_s) [A] [Std. Error]	Mean ln(P_{s+1}) [A] [Std. Error]	*t*-value	Probability	Average multiplier [B] ($\hat{\mu}_{z_s}$)	N
1 to 2	6.36 [0.014]	6.30 [0.014]	2.805	0.0051	0.945	818
2 to 3	6.31 [0.016]	6.24 [0.016]	2.902	0.0038	0.936	576
3 to 4	6.23 [0.017]	6.15 [0.016]	3.114	0.0019	0.930	384
4 to 5	6.18 [0.018]	6.13 [0.017]	2.205	0.0279	0.948	277
5 to 6	6.16 [0.018]	6.09 [0.019]	2.784	0.0056	0.930	205
6 to 7	6.11 [0.024]	6.06 [0.023]	1.462	0.1449	*0.953* [C]	131
7 to 8	6.11 [0.032]	6.06 [0.031]	1.326	0.1872	*0.943* [C]	68

[A] Units are ln(MJ/m^2/yr.)

[B] Average multiplier is in the form described in Equation 3.2. As such, it is calculated in this table using the ratio of the inverse natural logarithms for both estimated means.

[C] Multiplier is not significantly different than 1.0 at conventional levels of significance ($p<0.05$).

The results in Table 4.1 confirm this hypothesis. At first, each additional certificate produces a consistent 5 to 7% reduction in energy use intensity on average. After the sixth certificate, $\hat{\mu}_{z_s}$ is not statistically different than 1, showing diminishing returns after 5 periods of certification. The consistency of multipliers less than 1 implies that frequent certification may also be inhibiting a return to pre-certification energy consumption.

One interesting observation is the similarity in final energy consumption between the 6th period of certification (sequence 6 to 7) and the 7th period of certification (sequence 7 to 8). The market appears to settle on a limit in average office asset energy use intensity of approximately 430 MJ/m^2/year. Assets with 8 certificates as of the time of this study appear to take longer to reach this equilibrium, which would explain the apparent persistence of the average energy efficiency multiplier to remain below 1. The next test sheds some light on why eight-certificate assets take longer to reach this equilibrium.

4.1.2 Test 2: Cumulative effect on energy performance

The second model is similar to the first, but instead of the marginal improvement between certificate s and s+1, this test looks at the cumulative improvement between the benchmark certificate and each re-certification period. Table 4.2 presents the results. As the number of re-certifications increase, there is extremely high confidence of improved energy efficiency over the benchmark distribution. Unequal sample variance may be a concern in regard to some of the comparisons, particularly those with a large gap between certification periods (see Table 3.2). Welch t-test results, which allow for unequal variance, were also examined and revealed no difference to the results in Table 4.2.

In the previous test, there was evidence that assets with eight certificates took longer to reach the hypothesised post-NABERS equilibrium. An explanation is provided in Table 4.2. Although $\hat{\mu}_{z_s}$ continues to increase up to the eighth certificate, increases past the 5th certificate are largely a product of the benchmark consumption rising as the population is reduced to assets with a relatively high number of re-certifications.

Table 4.2. Results of t-tests between the benchmark certificate and each re-certification period.

Sequence 1 to s	Mean ln(P_1) [A] [Std. Error]	Mean ln(P_s) [A] [Std. Error]	t-value	Probability	Average multiplier [B] ($\hat{\mu}_{z_s}$)	N
1 to 2	6.36 [0.014]	6.30 [0.014]	2.805	0.0051	0.945	818
1 to 3	6.36 [0.016]	6.24 [0.016]	5.312	1.30 x 10^{-7}	0.888	576
1 to 4	6.35 [0.016]	6.15 [0.016]	8.687	2.22 x 10^{-17}	0.819	384
1 to 5	6.38 [0.018]	6.13 [0.017]	10.343	4.88 x 10^{-23}	0.777	277
1 to 6	6.42 [0.019]	6.09 [0.019]	12.498	1.37 x 10^{-30}	0.717	205
1 to 7	6.41 [0.022]	6.06 [0.023]	10.885	5.55 x 10^{-23}	0.704	131
1 to 8	6.44 [0.026]	6.06 [0.031]	9.722	3.10 x 10^{-17}	0.679	68

[A] Units are ln(MJ/m^2/yr.)

[B] Average multiplier is in the form described in Equation 3.2. As such, it is calculated in this table using the ratio of the inverse natural logarithms for both estimated means.

Assets with the most re-certifications are those that entered NABERS certification as early voluntary adopters. This leads to two potential interpretations of the inflating average benchmark EUI seen in Table 4.2. Late adopters may be more energy efficient as a result of spillover effects, which are benefits to non-participants from the introduction of a voluntary certification scheme (Borck and Coglianese, 2009). Alternatively, the descriptive statistics in Chapter 3 showed the population of early adopters is more likely to be composed of large assets and more likely to be located in a capital city CBD. Hence, a subsample bias could be responsible for inflated average benchmark EUI in early adopters.

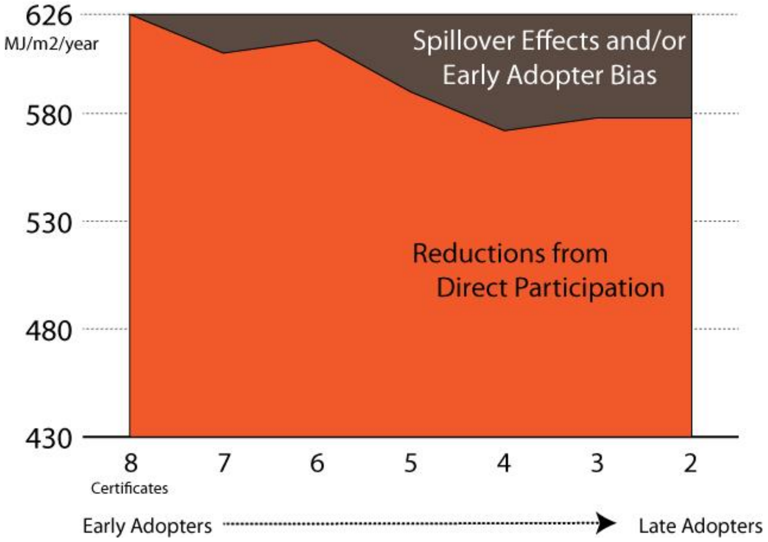

Figure 4.1. Graphical illustration of declining average benchmark EUI over time (as proxied by number of certificates per asset). The earliest cohort of assets to pursue NABERS Energy certification averaged 626 MJ/m^2/year (logarithmic average), while the entire population averaged 580 MJ/m^2/year; the decline appears to be a steady trend that can either be explained by spillover effects, bias in the sub-population of early adopters, or both.

Figure 4.1 describes this observation graphically. Assume that the observed value of 430 MJ/m^2/year is the post-NABERS Energy participation equilibrium for the building stock in Australia. Given an infinite number of certification periods, the population will consume this amount of energy on average, all else being equal. The orange area in Figure 4.1 estimates expected energy savings per asset as a result of infinite participation in NABERS Energy; because later adopters start at a lower average benchmark EUI (Table 4.2), energy saved per asset declines as one moves from early adopters to late adopters. The brown area above measures spillover effects if one assumes all assets consumed 626 MJ/m^2/year (equal to a log-transformed value of 6.44) at the time early adopters entered NABERS; or it measures an initial overestimation of energy savings if one assumes early adopters are an unrepresentative sample; or it represents some combination of both factors.

Figure 4.2 plots the cumulative and marginal multiplier results as a function of the number of certifications for each asset. The cumulative multiplier (blue line) begins to level out after the sixth certificate, approaching an asymptote of approximately two-thirds of the average initial benchmark consumption, though continued decline may be overestimated as a result of unmeasured bias associated with early adopters as described above. This levelling out occurs at the same time that the marginal multiplier becomes insignificantly different from 1. Hence one can conclude that the majority of the benefits of NABERS Energy certification – as implemented during the 14 years of this study – have been obtained by the sixth certificate, which is typically acquired between five and six years after the initial benchmark certificate.

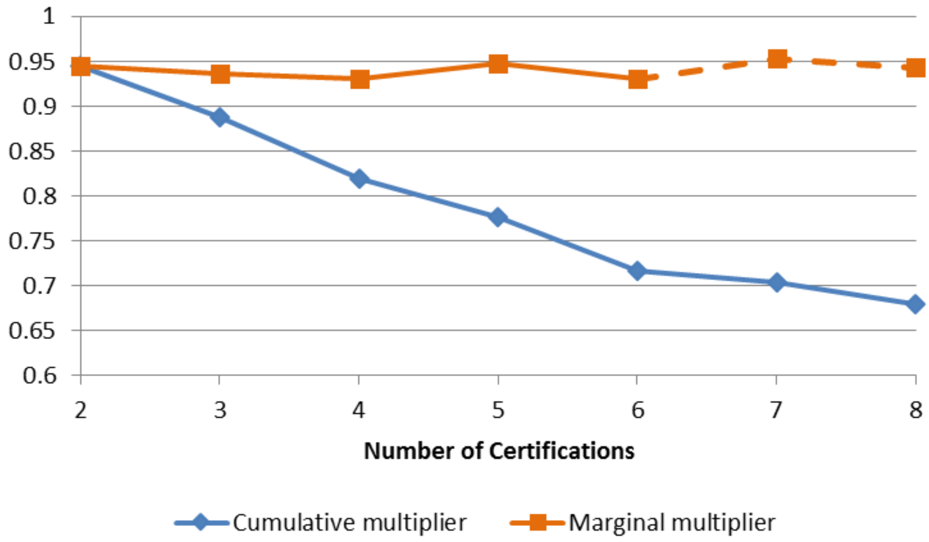

Figure 4.2. The path of energy savings as a result of repeat participation in NABERS Energy certification. The orange line presents the marginal multipliers (Test 1) for each certification period relative to the previous certificate. Dashed lines indicate statistical indifference from the value of 1. The blue line is the cumulative multiplier (Test 2) measuring energy consumption relative to an initial benchmark certificate.

The next two sections present the multivariate regressions that attempt to control for other exogenous factors besides the intervention of NABERS Energy.

4.1.3 Test 3: Multiple variables and the effect of an additional certificate

The *t*-tests assume that outcomes from the intervention of NABERS Energy are uniform over the entire dataset and other exogenous factors such as green management strategy have no effect in the absence of NABERS Energy. To relax these assumptions, a multivariate least squares regression describes variation within the population and accounts for measurable exogenous determinants of energy consumption improvement. The dependent variable is the change in EUI between an asset's most recent NABERS Energy certificate and its initial benchmark certificate. Results from the four specifications described in Section 3.3.3 are presented in Table 4.3. The first specification describes the entire dataset while specifications 2, 3 and 4 model subsamples where additional data on asset characteristics are available.

The variable of interest is represented by the vector of binary variables representing depth of participation in NABERS Energy. Depth of participation is measured as the number of certificates obtained by each asset in the dataset. The dependent variable will be negative if an asset reduces its EUI, so the significant negative coefficient as the number of certificates increase reveals a strong association between depth of participation in NABERS Energy and energy efficiency outcomes.

Table 4.3. Regression results with a dependent variable of change in EUI between an asset's most recent NABERS Energy certificate ($\boldsymbol{P}_{j_{s=max}}$) and its initial benchmark certificate ($\boldsymbol{P}_{j_{s=1}}$). Standard error in brackets.

	Spec. 1 (All Obs.)	**Spec. 2 (All NLA Obs.)**	**Spec. 3 (Rated Hrs. Obs.)**	**Spec. 4 (Sydney CBD)**
Depth of Participation				
Two Certificates	*Reference*	*Reference*	*Reference*	*Reference*
Three Certificates	-1.38 (16.60)	-2.64 (17.01)	8.66 (19.08)	-207.73 (58.54) ***
Four Certificates	-77.00 (20.2) ***	-77.61 (20.7) ***	-66.98 (23.0) ***	-200.18 (63.99) ***
Five Certificates	-88.65 (23.1) ***	-87.62 (23.6) ***	-75.64 (25.1) ***	-242.51 (71.36) ***
Six Certificates	-128.20 (23.79) ***	-126.26 (24.53) ***	-111.27 (26.37) ***	-253.42 (65.25) ***
Seven Certificates	-129.77 (25.46) ***	-126.59 (26.18) ***	-114.25 (27.84) ***	-303.72 (68.14) ***
Eight Certificates	-118.54 (25.46) ***	-115.60 (26.13) ***	-100.87 (27.60) ***	-228.59 (67.86) ***
Asset Location				
State ACT	*Reference*	*Reference*	*Reference*	
State NSW	1.01 (29.77)	-2.44 (30.27)	-26.30 (36.89)	
State QLD	99.57 (36.59) ***	92.25 (37.2) **	80.03 (43.89) *	
State SA	10.42 (80.76)	-0.3 (81.39)	63.4 (175.14)	
State VIC	46.39 (33.67)	42.75 (34.11)	22.95 (40.18)	
State WA	-26.10 (46.85)	-39.69 (48.46)	-66.16 (57.93)	
State Other	-50.62 (69.61)	-71.09 (75.73)	-112.11 (105.48)	
CBD Canberra	24.38 (40.19)	17.24 (40.76)	-5.48 (51.22)	
CBD Sydney	-13.22 (19.14)	-8.82 (19.91)	-23.31 (21.51)	
CBD Brisbane	-71.55 (31.57) **	-64.85 (32.34) **	-86.05 (35.14) **	
CBD Adelaide	-52.23 (81.55)	-45.81 (82.46)	-128.27 (175.51)	
CBD Melbourne	-18.49 (27.59)	-12.02 (28.37)	-27.27 (29.72)	
CBD Perth	13.92 (45.29)	26.65 (47.03)	26.27 (53.20)	
CBD Other	-14.03 (80.46)	37.73 (94.90)	52.29 (126.12)	
Asset Characteristics				
Nat. Log. Asset NLA		-9.73 (9.17)	-12.91 (10.35)	21.35 (29.35)
Rated Hours (per week)			1.150 (0.904)	
Premium Grade				58.27 (51.42)
A-Grade				*Reference*
B- or C-Grade				110.25 (37.45) ***
Asset Age (in 2011)				-2.02 (1.06) **
Capacity to Improve				
Initial EUI	-0.342 (0.02) ***	-0.345 (0.02) ***	-0.358 (0.02) ***	-0.411 (0.06) ***
Owner Characteristics				
Green Power Purchased	-49.00 (18. 8) ***	-46.25 (18.99) **	-49.01 (20.72) **	-115.18 (39.61) ***
Green Owner*Initial EUI	-0.079 (0.03) ***	-0.075 (0.03) ***	-0.083 (0.03) ***	-0.130 (0.05) ***
Avg. Days Between Certs. (Nat. Log.)	27.73 (14.66) *	31.24 (14.87) **	22.51 (17.42)	36.49 (43.45)
Intercept (α)	-3.35 (96.40)	69.34 (127.92)	118.07 (145.64)	-59.81 (337.54)
N	**818**	**806**	**696**	**119**
R-squared	**0.363**	**0.365**	**0.381**	**0.547**
Adj. R-squared	**0.344**	**0.345**	**0.358**	**0.486**

*, ** and *** indicate *p* values less than 0.10, 0.05, and 0.01 respectively.

With some adjustments to the univariate data, it is possible to compare the multivariate coefficients with the univariate model in Figure 4.2. Specification1 in Table 4.3 is used because it is the same sample as the univariate model and additional data on asset characteristics in specifications two and three appear to be unrelated to energy efficiency. Two intermediate steps are necessary. First, the multiplier from Figure 4.2 needs to be converted into the dependent variable of change in energy consumption. Using the data in Table 4.2, the expected value of the change in energy consumption from each univariate model is calculated as such:

$$E(\Delta P_s) = e^{\ln(P_1)}\left(\hat{\mu}_{z_s} - 1\right) \tag{4.1}$$

The second adjustment is to modify $E(\Delta P_s)$ so it is relative to the second certificate; Equation 4.1 calculates the expected change relative to the initial benchmark certificate. Thus, each value of $E(\Delta P_s)$ for s>2 is reduced by $E(\Delta P_2)$. Table 4.4 presents the results of these adjustments on the univariate results, which are compared with specification one of the multivariate model in Figure 4.3.

Table 4.4. Adjustment of the results from the second univariate test to be comparable with the multivariate regression estimation.

Sequence 1 to s	**Mean ln(P₁)**	**Average multiplier ($\hat{\mu}_{z_s}$)**	$E(\Delta P_s)$	$E(\Delta P_s) - \Delta P_2$
1 to 2	6.36	0.945	-31.80	*Reference*
1 to 3	6.36	0.888	-64.760	-32.96
1 to 4	6.35	0.819	-103.62	-71.82
1 to 5	6.38	0.777	-131.55	-99.75
1 to 6	6.42	0.717	-173.76	-141.96
1 to 7	6.41	0.704	-179.94	-148.13
1 to 8	6.44	0.679	-201.08	-169.27

The univariate and multivariate results are in good agreement, with the multivariate model typically showing a relatively lower reduction in energy consumption as a function of participation depth. This is logical because the multivariate model has additional control variables explaining change in energy efficiency that are weakly correlated with the number of certificates obtained, such as green management strategy.

The one notable deviation from the agreement between models occurs at the eighth certificate. All multivariate model specifications show a marginal increase in energy consumption relative to the seventh certificate while the univariate trend continues to model a decrease in energy consumption. This observation suggests that the multivariate model is better able to attribute any additional increase in energy savings past the sixth certificate to other factors besides participation in NABERS Energy. The multivariate curve in Figure 4.3 is even stronger support to the conclusion that NABERS Energy has little effect on asset energy consumption after the sixth certificate; post-certification equilibrium is reached approximately five to six years after an asset enters NABERS Energy.

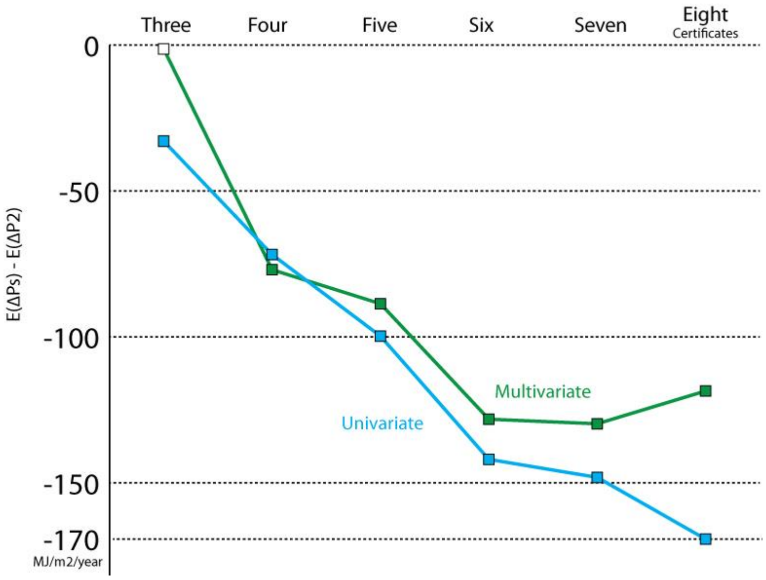

Figure 4.3. Comparison between Test 2 (univariate) and Test 3, specification 1, (multivariate) results for the expected change in asset energy consumption as a function of the depth of NABERS Energy participation (number of certificates obtained).

Capacity for improvement, measured as initial EUI, is the strongest control variable in all specifications. As expected, an asset with higher initial EUI produces higher energy savings, as measured by the change in energy consumption relative to the benchmark, if all other characteristics are equal. The interaction between green ownership and initial EUI reveals that assets with a green management strategy are successful in reducing energy consumption beyond the model's expectation for an average owner. However, one must use caution in regard to interpretation of the green strategy variable; observations in Chapter 3 showed that green strategy is correlated with large buildings, which are typically owned by large funds that have better access to investment capital. More data is needed on access to capital to separate this effect from the consequence of green strategy adoption. For the purposes of this model, the green owner variable appears sufficient to control for owner characteristics that have an effect on energy efficiency, even though there is uncertainty regarding what specific characteristic is important.

Assets whose owners purchase Green Power have significantly more energy consumption reductions in all specifications. This observation suggests that Green Power offsets are used to complement operational energy efficiency, not substitute for it. It also suggests this variable identifies "super-green" assets with owners that are willing to go beyond operational energy efficiency to meet green strategy objectives, even though these owners will not benefit from Green Power purchases in the energy rating that must be disclosed under the BEED Act.

The locational controls in this model reveal that, in nearly all cases, outcomes for investment in operational energy efficiency are not significantly influenced by local policies, interstate economic differentiation, or climate. Queensland is the one exception. In particular, office assets outside the CBD of the capital, Brisbane, reduce energy consumption less than the rest of the country after any given depth of participation in NABERS Energy. Climate may be one factor; the populated areas of Queensland are located in warmer and more humid environments than other Australian cities. In addition, following the introduction of NABERS Energy, Queensland has suffered from major tropical cyclones and flooding that may have interrupted investment in energy efficiency. But Brisbane is in this environment and experienced one of the major flood events in 2011, so the Queensland climate is not a clear barrier to energy efficiency. A unique suburban office boom in the markets around Brisbane (Figure 2.6) suggests that high demand for suburban assets allowed little scope for consumers of office space to discriminate on energy consumption. The boom could also be associated with investment in new assets already performing at a high level of energy efficiency. But Brisbane CBD and Perth CBD also underwent similar booms (Figure 2.5), although the greater number of office assets in a CBD relative to a suburban office park gives consumers greater scope to discriminate on energy performance. Thus the lack of energy efficiency in Queensland outside Brisbane is likely due to a combination of a challenging climate for energy efficiency, the incidence of natural disasters during the study period, and market conditions in a booming suburban office sector.

The only other control variable that has an effect on change in energy consumption in most specifications is the average number of days between certificates. But it is in an unexpected direction; assets with more time between certificates reduce energy consumption *less* than assets with fewer days between certificates. This suggests that the variable is accounting for expectations; assets committed to undertake regular NABERS Energy audits invest more in energy efficiency than those assets that participate in NABERS Energy infrequently. Hence it can be concluded that expectations of future audits are an important component of investment in energy efficiency.

As for the additional asset characteristics added in specifications two and three, it appears that reductions in energy consumption are not associated with asset size or intensity of use. The coefficients suggest larger buildings are marginally more likely to reduce energy consumption than smaller buildings and buildings with longer operating hours are marginally less likely to reduce energy consumption than those with shorter operating hours. But neither coefficient is statistically significant, so it can be concluded that if one accounts for all the variables in specification one (i.e. capacity to improve, location and owner characteristics), inherent asset size and intensity of use does not further explain energy efficiency outcomes. Of course, if intensity of use was allowed to vary, then it would be expected to be positively associated with changes in energy consumption; as a building is operated for longer hours, it consumes more energy. But data on Rated Hours is only available for a subsample of the most recent NABERS Energy certificates, so this model has to assume a fixed intensity of use.

The Sydney subsample in specification four finds larger negative coefficients representing energy consumption reductions as a function of participation in NABERS Energy. This is because as a sub-population, Sydney CBD office assets had much higher benchmark energy consumption on average than the entire energy dataset (Table 3.7). This difference in average starting energy consumption is responsible for much of the variation in NABERS participation coefficients between specifications one and four. The remainder is likely due to the unique characteristics of the Sydney market; specification one shows a minor "Sydney CBD effect" of increased energy savings in the locational variables, though the coefficient is insignificant relative to the rest of the dataset.

Specification four also reveals B- and C-Grade assets are less likely to reduce energy consumption than Premium and A-Grade assets. Understanding this observation is an interesting scope for future research. In my discussions with the property industry in Sydney, four hypotheses have arisen. One possibility is that environmental quality is a "luxury good" in the property sector (see Fuerst *et al.* 2013); it can be used to differentiate assets wishing to attract investment-grade tenants adhering to corporate social responsibility standards. Second, prospective tenants for secondary-grade assets may not be as sensitive to environmental quality as prospective tenants for premium-grade assets and thus are less willing to pay for energy efficiency. Some indirect evidence of this hypothesis is seen outside of Sydney when comparing the high Energy Star rent premiums of Wiley *et al.* (2010), who only studied A-Grade assets in the United States, with lower Energy Star rent premiums from authors not restricting themselves to A-Grade assets (Eichholtz *et al.*, 2010, Fuerst and McAllister, 2011b). In the context of Sydney, Appendix 3 in this thesis observes that prime-grade tenants pay rents as a function of energy consumption, but this preference is so weak that it cannot be detected in the sample of the whole population. The third possibility is that asset quality is a proxy for an owner characteristic. In similar logic to the earlier discussion regarding green ownership, B-Grade asset owners may not have as much access to the investment capital needed for energy upgrades as owners of A-Grade assets. Finally, the fourth hypothesis considers the association between level of services provided and energy consumption; Premium and A-Grade assets provide more services to tenants than secondary-grade assets, therefore they have more energy conservation potential.

Asset age was also included in specification four, finding that older assets reduce energy consumption more than younger assets. While it is tempting to assume that this is confirmation of the common assertion that older buildings are more energy inefficient (Kok and Jennen, 2012), thus have more capacity to improve, the inclusion of initial EUI in the model controls for this relationship. Instead, older assets are more likely to be scheduled for major renovations and there is usually a wider scope for energy efficiency investment in these cases (such as replacing an entire mechanical conditioning system). Energy efficiency investment in younger assets may be restricted to management interventions and other less intense forms of investment such as light-bulb replacement.

As a whole, each model explains between 34 and 49% of the variability in the change in energy consumption relative to a NABERS Energy benchmark certificate. Appendix 1 shows that the explanatory power of the model is much higher when the dependent variable is an asset's most recent measurement of EUI ($P_{j_{(s=max)}}$) instead of the change in energy consumption (ΔP_j). This is because the control variable for capacity to improve, the initial benchmark EUI, is an excellent predictor of an asset's most recent EUI. But in Appendix 1, the coefficients for the variables of interest and control variables are identical, so it is more interesting to understand how much the model explains the change in energy consumption. Keeping in mind that energy savings are not automatically correlated with investment – many assets with large investments in energy efficiency fail to perform in practice (Newsham *et al.*, 2009) – the explanatory power of this model is comparable to estimations of factors that influence the construction of new energy efficient assets (Kok *et al.*, 2012a, Fuerst *et al.*, forthcoming).

There is one major concern with this model, however. The descriptive statistics in Chapter 3 found high correlation between the number of certificates obtained by an asset and the year of an asset's benchmark NABERS Energy certification. This means that the "treatment" assigned to each asset is unclear: do assets with seven NABERS Energy certificates reduce their energy consumption by 130 MJ/m^2/year on average because they have participated in the scheme for seven periods or because it was advantageous to enter the scheme in 2006? Instead of measuring depth of participation in NABERS Energy, the variable of interest could represent unobserved fixed time effects. Chapter 3 observed a change in the data around the introduction of mandatory disclosure, while the univariate models in this chapter found a potential signature of spillover effects (Figure 4.1) in the gradual decline of average benchmark EUI over time.

Table 4.5. Regression results with a dependent variable of change in EUI between an asset's second NABERS Energy certificate and its initial benchmark certificate. Standard error in brackets.

	Spec. A (Year Binaries)	**Spec. B (Conservative MD)**	**Spec. C (Moderate MD)**	**Spec. D (Liberal MD)**
Fixed Time Effects				
Benchmark 1999-2003	*Reference*			
Benchmark 2004	-28.42 (38.85)			
Benchmark 2005	-40.90 (34.11)			
Benchmark 2006	-59.30 (31.32) *			
Benchmark 2007	-40.04 (35.29)			
Benchmark 2008	-52.67 (39.56)			
Benchmark 2009	-20.89 (33.96)			
Benchmark 2010	-16.90 (31.28)			
Benchmark 2011	-84.09 (33.38) **			
Benchmark 2012-2013	-61.27 (37.13) *			
Mandatory Adopter		-28.09 (15.61) *	7.21 (15.57)	5.58 (16.17)
Voluntary Adopter		*Reference*	*Reference*	*Reference*
Asset Location				
State ACT	*Reference*	*Reference*	*Reference*	*Reference*
State NSW	2.20 (31.56)	3.71 (31.51)	4.02 (31.59)	3.48 (31.58)
State QLD	25.40 (38.78)	22.72 (38.7)	23.07 (38.81)	22.19 (38.77)
State SA	-26.80 (85.20)	-31.91 (84.97)	-30.04 (85.13)	-29.19 (85.17)
State VIC	48.90 (36.01)	45.68 (35.8)	41.94 (35.97)	39.18 (35.81)
State WA	-15.60 (50.75)	-22.17 (50.49)	-24.09 (50.63)	-25.23 (50.56)
State Other	-91.90 (79.08)	-85.39 (79.28)	-90.06 (79.40)	-89.77 (79.40)
CBD Canberra	20.86 (42.44)	20.94 (42.29)	22.68 (42.40)	24.61 (42.44)
CBD Sydney	-8.59 (20.95)	-13.34 (20.8)	-11.72 (20.86)	-10.48 (20.86)
CBD Brisbane	-26.75 (33.71)	-28.31 (33.74)	-29.03 (33.80)	-28.87 (33.80)
CBD Adelaide	-8.29 (86.33)	-9.99 (86.19)	-12.31 (86.35)	-12.21 (86.36)
CBD Melbourne	-40.77 (29.75)	-40.68 (29.75)	-38.38 (29.81)	-37.14 (29.78)
CBD Perth	15.37 (48.94)	18.55 (48.87)	19.95 (48.96)	20.02 (48.96)
CBD Other	72.05 (99.39)	52.65 (99.45)	57.7 (99.63)	58.98 (99.58)
Asset Characteristics				
Nat. Log. Asset NLA	-3.74 (9.46)	-2.01 (9.35)	-0.24 (9.41)	1.04 (9.37)
Capacity to Improve				
Initial EUI	-0.202 (0.02) ***	-0.203 (0.02) ***	-0.209 (0.02) ***	-0.211 (0.02) ***
Owner Characteristics				
Green Power Purchased	-26.69 (19.84)	-30.8 (19.55)	-27.76 (19.64)	-26.00 (19.48)
Green Owner*Initial EUI	-0.032 (0.029)	-0.041 (0.027)	-0.037 (0.028)	-0.031 (0.028)
Days Between Certs. 1 and 2 (Nat. Log.)	6.38 (13.46)	6.9 (11.73)	11.84 (12.14)	16.33 (12.66)
Intercept (α)	133.90 (141.06)	87.01 (118.68)	37.07 (123.48)	-9.29 (127.94)
N	806	806	806	806
R-squared	0.139	0.125	0.121	0.121
Adj. R-squared	0.109	0.104	0.100	0.100

MD is an abbreviation for Mandatory Disclosure.

*, ** and *** indicate *p* values less than 0.10, 0.05, and 0.01 respectively.

4.1.4 Test 4: The influence of fixed time effects

To address the concern regarding fixed time effects, three additional models are run. In these models the number of certificates is fixed and independent variables relating to time effects are the variables of interest. The three models freeze the certification process at the second, third and fourth NABERS Energy certificate. Each model's dependent variable is the change in energy consumption between the certificate of interest (second, third or fourth) and the initial benchmark certificate for each asset. In each model, four specifications representing a flexible functional form of fixed time effects and three definitions of mandatory adopter are run on each model. Refer to Section 3.3.4 for the full specification of each model.

4.1.4.1 Two-certificate model

Table 4.5 contains the results for the two-certificate model, where the dependent variable is the change in energy consumption between an asset's second NABERS Energy certificate and its initial benchmark certificate. Specification A suggests that at the time of an asset's second certificate there are weak fixed time effects in 2006, 2011 and 2012-13, as measured in reference to the earliest adopters. Assets commencing NABERS Energy certification in these years are statistically more likely to have greater reductions in energy consumption at the time of an asset's second certificate, if all else is held constant. Specification B suggests that the group of assets considered mandatory adopters under the conservative definition (commencing after 1 November 2010) are more likely to have greater reductions in energy consumption at the time of the second certificate than voluntary adopters. Otherwise, the only other predictor of energy savings at the time of an asset's second certificate is the capacity to improve, as measured by initial EUI. Expanded definitions of mandatory adopter produce no significant effect.

Other variables that were significant in the first model, such as green ownership and the choice to purchase Green Power offsets, have smaller coefficients in the same direction as the first model, but in this model, they are not statistically significant. As a whole, the model presented in Table 4.5 only explains approximately 10% the change in EUI between an asset's first and second NABERS Energy certificates. Both of these observations make sense in the context of what the two-certificate model is trying to explain. The median number of days between an asset's first and second certificate is only 448 days (Table 3.5). NABERS Energy audits use a full year of consumption data. For the median asset, this means that energy consumption measured during the second audit begins approximately 3 months after the first certificate's audit is complete[1]. This is a short lag time that only allows for the simplest of interventions to improve energy

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[1] For this to be true, the lag between energy audit and certificate issuance must be identical in both periods. Without data on audit dates, which are unavailable, this assumption is necessary.

consumption; large capital investment in energy efficiency is not likely to affect consumption at the time of the second certificate. Referencing the model of participation depth, it was not until the fourth certificate that participation in NABERS Energy is able to explain energy outcomes.

Specification A also tells an interesting story that suggests the speed of energy savings is a function of national awareness of energy performance or greenhouse gas emissions. It observes that 2006 and post-mandatory disclosure years have significantly higher energy savings relative to early adopters after the second certificate. Other years are not significantly different. Assuming that the number of buildings commencing NABERS Energy certification is correlated with national awareness of building energy consumption (or, by extension, interest in the mitigation of greenhouse gas emissions), Figure 3.12 clearly shows that 2006 and late 2010 are peaks in national awareness. The coincidence that assets commencing certification soon after these periods are faster to reduce energy than assets commencing at other times suggests that national awareness may be responsible for faster energy savings. However, as the next two models suggest, awareness does not necessarily lead to more energy consumption savings as an asset moves closer to a post-certification equilibrium.

4.1.4.2 Three-certificate model

Results of the model testing for the influence of fixed time effects on operational energy consumption reductions after three NABERS Energy certificates are presented in Table 4.6. Relative to the two-certificate model, a number of notable changes occur. First, there are no fixed time effects that register as statistically significant. Second, control variables such as green ownership, location in Queensland, and Green Power offset purchases are significant in a similar manner to the original model specification that omitted fixed time effects. Third, the overall explanatory power of the model increases relative to the two-certificate model, as one would expect given these assets are a subsample that is closer to a post-certification equilibrium. However, the explanatory power is still much less than the original model specification. Investments in energy efficiency have had over a year, on average, to influence NABERS Energy audit results, but this model is still attempting to measure a trend in the middle of a transition to a new equilibrium.

The insignificance of all benchmark year variable coefficients suggests that the year of commencement is unrelated to energy conservation outcomes by the time an asset has undergone its third NABERS Energy audit. National awareness may have led to larger gains at the second audit for assets starting in 2006 and after mandatory disclosure enforcement began, but by the third audit, assets starting in other years have “caught up” with statistically similar energy reductions. Hence there is no reason to believe that the coefficient for a depth of participation in NABERS Energy of three certificates is biased by time effects in the first model.

Table 4.6. Regression results with a dependent variable of change in EUI between an asset's third NABERS Energy certificate and its initial benchmark certificate. Standard error in brackets.

	Spec. A (Year Binaries)	**Spec. B (Conservative MD)**	**Spec. C (Moderate MD)**	**Spec. D (Liberal MD)**
Fixed Time Effects Benchmark 1999-2003	*Reference*			
Benchmark 2004	-11.42 (37.77)			
Benchmark 2005	-22.53 (32.43)			
Benchmark 2006	-21.86 (31.45)			
Benchmark 2007	-30.09 (36.24)			
Benchmark 2008	17.38 (41.72)			
Benchmark 2009	12.84 (36.60)			
Benchmark 2010	-11.35 (35.89)			
Benchmark 2011-2012	14.76 (41.40)			
Mandatory Adopter		14.88 (20.68)	0.93 (18.41)	17.07 (18.39)
Voluntary Adopter		*Reference*	*Reference*	*Reference*
Asset Location State ACT	*Reference*	*Reference*	*Reference*	*Reference*
State NSW	-11.12 (36.36)	-8.68 (36.04)	-7.42 (36.05)	-7.68 (35.98)
State QLD	104.03 (46.17) **	106.97 (45.56) **	108.28 (45.6) **	108.91 (45.50) **
State SA	70.95 (169.62)	74.78 (166.68)	77.01 (166.75)	75.96 (166.60)
State VIC	-19.16 (42.25)	-16.94 (41.70)	-14.30 (41.93)	-16.59 (41.58)
State WA	-29.27 (81.47)	-32.94 (80.25)	-28.41 (80.06)	-25.88 (80.01)
State Other	23.88 (101.51)	30.16 (100.80)	33.66 (100.73)	33.80 (100.65)
CBD Canberra	19.60 (46.33)	24.81 (45.60)	24.81 (45.65)	27.19 (45.66)
CBD Sydney	-14.09 (21.93)	-12.51 (21.66)	-13.85 (21.65)	-12.46 (21.62)
CBD Brisbane	-108.58 (39.52) ***	-110.01 (39.33)***	-109.96 (39.4) ***	-109.87 (39.32) ***
CBD Adelaide	-125.96 (169.58)	-129.75 (167.08)	-129.90 (167.2)	-127.25 (167.05)
CBD Melbourne	-21.27 (34.15)	-18.45 (33.94)	-20.14 (33.98)	-19.12 (33.86)
CBD Perth	-0.06 (78.28)	1.57 (77.38)	-0.55 (77.38)	-3.23 (77.36)
CBD Other	-83.87 (119.19)	-79.24 (118.83)	-79.27 (118.89)	-80.98 (118.81)
Asset Characteristics Nat. Log. Asset NLA	13.59 (10.80)	14.26 (10.63)	14.07 (10.69)	14.74 (10.65)
Capacity to Improve Initial EUI	-0.250 (0.03) ***	-0.258 (0.03) ***	-0.254 (0.03) ***	-0.254 (0.03) ***
Owner Characteristics Green Power Purchased	-39.55 (20.33) *	-38.48 (19.89) *	-39.93 (19.97) **	-38.79 (19.81) *
Green Owner*Initial EUI	-0.036 (0.029)	-0.044 (0.027)	-0.047 (0.027) *	-0.040 (0.028)
Avg. Days Between Certs. 1 to 3 (Nat. Log.)	33.40 (24.05)	29.64 (17.44) *	25.68 (18.74)	36.34 (20.24) *
Intercept (α)	-218.38 (206.12)	-207.92 (150.24)	-182.23 (161.0)	-263.79 (171.21)
N	571	571	571	571
R-squared	0.211	0.205	0.204	0.205
Adj. R-squared	0.173	0.177	0.176	0.178

MD is an abbreviation for Mandatory Disclosure.

*, ** and *** indicate *p* values less than 0.10, 0.05, and 0.01 respectively.

4.1.4.3 Four-certificate model

Table 4.7 contains the results for the four-certificate model, where the dependent variable is the change in energy consumption between an asset's fourth NABERS Energy certificate and its initial benchmark certificate. Due to the reduction in sample size, from 806 in the two-certificate model to 382 in this model, a number of adjustments were made to this model. No assets in Tasmania or Northern Territory have obtained four or more NABERS Energy certificates. In addition, all South Australia assets are located within the capital city, Adelaide, so there is no CBD Adelaide variable. Finally, as was mentioned in Chapter 3, there are an insufficient number of assets meeting the conservative definition of mandatory adoption to enable the constriction of specification B in this model.

Like the three-certificate model, all time effects considered have an insignificant effect on the change in energy consumption at the time of the fourth NABERS Energy audit. By the time an asset participates in four certification processes, the year of its first certification is irrelevant. Identifying owners motivated by upcoming mandatory disclosure regulation does not increase the power of the model to explain operational energy savings. Hence it can be concluded that time effects are not important at the time an asset obtains its fourth certificate.

Initial EUI is able to explain close to one-third of the variance in energy savings at the time of an asset's fourth certificate. In this model, green ownership and Green Power variables go back to being statistically insignificant, though the coefficients are in the same direction as all other models. One reason for this may be the uniqueness of the subsample: green owners and purchasers of Green Power offsets are much more prevalent as a percentage of total assets in this sample when compared with the entire dataset (see Table 3.5). Hence the model may not be able to attribute enough of the additional savings to green strategy as it was able to do for the three-certificate model; instead these savings appear within the coefficient for initial EUI that represents the entire cohort. Second, the additional energy savings attributed to green owners and purchasers of Green Power offsets in the original model may be a product of consistent marginal savings at each threshold. For example, the three-certificate model has a weakly significant Green Power coefficient and the two- and four-certificate models have the expected negative coefficient, but the standard error is too large for them to be considered significant. However, the net outcome, as seen in the original model, is a much larger and very significant negative coefficient for Green Power offset purchasers when each asset is measured as close to its post-certification energy performance as is possible. The variable for green ownership strategy behaves similarly.

The South Australia state variable suggests significant energy reduction in that state at the time of the fourth certificate. However, this likely reflects the situation that all four-certificate observations in South Australia are located in the capital city, Adelaide, where a competitive office market may encourage asset positioning via energy efficiency.

Table 4.7. Regression results with a dependent variable of change in EUI between an asset's fourth NABERS Energy certificate and its initial benchmark certificate. Standard error in brackets.

	Spec. A (Year Binaries)	**Spec. B (Conservative MD)**	**Spec. C (Moderate MD)**	**Spec. D (Liberal MD)**
Fixed Time Effects Benchmark 1999-2003	*Reference*	INSUFFICIENT MANDATORY ADOPTERS		
Benchmark 2004	-9.08 (32.57)			
Benchmark 2005	-39.47 (28.82)			
Benchmark 2006	-19.76 (28.65)			
Benchmark 2007	-28.32 (33.62)			
Benchmark 2008	21.80 (37.29)			
Benchmark 2009	-24.00 (35.50)			
Benchmark 2010-2011	-29.45 (38.87)			
Mandatory Adopter			-10.63 (23.69)	-11.99 (19.38)
Voluntary Adopter			*Reference*	*Reference*
Asset Location State ACT	*Reference*		*Reference*	*Reference*
State NSW	-29.17 (40.08)		-23.55 (39.57)	-22.12 (39.7)
State QLD	-22.79 (49.77)		-15.74 (49.37)	-16.6 (49.02)
State SA	-95.45 (55.67) *		-93.56 (54.61) *	-94.07 (54.6) *
State VIC	-31.33 (47.63)		-25.24 (47.18)	-24.87 (46.87)
State WA	-70.47 (77.78)		-81.33 (76.88)	-82.11 (76.58)
CBD Canberra	-50.88 (47.42)		-44.62 (46.78)	-43.81 (46.81)
CBD Sydney	3.78 (21.43)		4.52 (21.15)	3.94 (21.17)
CBD Brisbane	11.16 (40.14)		10.46 (39.96)	10.51 (39.92)
CBD Melbourne	-12.07 (36.11)		-12.54 (35.94)	-11.44 (35.66)
CBD Perth	-0.07 (72.74)		10.62 (72.04)	10.75 (72.01)
Asset Characteristics Nat. Log. Asset NLA	-3.46 (11.13)		-3.51 (11.00)	-3.54 (10.99)
Capacity to Improve Initial EUI	-0.511 (0.04) ***		-0.513 (0.04) ***	-0.517 (0.04) ***
Owner Characteristics Green Power Purchased	-15.03 (19.09)		-14.63 (18.73)	-13.95 (18.51)
Green Owner*Initial EUI	-0.015 (0.026)		-0.024 (0.025)	-0.026 (0.025)
Avg. Days Between Certs. 1 to 4 (Nat. Log.)	40.15 (31.04)		47.03 (21.94) **	42.95 (23.92) *
Intercept (α)	41.28 (238.16)		-20.36 (171.64)	9.23 (184.95)
N	382		382	382
R-squared	0.381		0.372	0.373
Adj. R-squared	0.343		0.345	0.345

MD is an abbreviation for Mandatory Disclosure.
*, ** and *** indicate *p* values less than 0.10, 0.05, and 0.01 respectively.

In specifications C and D, a significant positive coefficient (less operational energy savings) is associated with longer time between certification periods. This observation is consistent with the pattern seen the original model, where a longer time between certificates may indicate an asset owner is disinterested in energy management strategies, knows he will not be audited regularly, and is thus less likely to succeed in reducing consumption.

4.1.5 Multicollinearity Test

In any multivariate model, multicollinearity between the variables of interest and other independent variables is a concern. Correlation could lead to inconsistent and biased coefficients, as well as inflated standard errors. For example, if nearly all three-certificate assets are uniquely located in the state of Queensland, the model cannot distinguish correctly between the "Queensland effect" and the effect of participating in NABERS Energy for three audit cycles. While the methodology in Chapter 3 was developed to minimise the influence of control variable correlation, most notably separating out the time effect in separate regressions, this section presents a key test for multicollinearity, the variance inflation factor, which aims to understand whether a variable of interest is correlated with any combination of control variables.

Belsley *et al.* (1980) describe the calculation of the variance inflation factor, or VIF, in detail. The intent is to understand how a multivariate linear regression can explain the vector of each independent variable with a matrix containing all other independent variables. A VIF of 1 indicates zero multicollinearity while a VIF of infinity indicates perfect multicollinearity (in which case the original model could never have been mathematically estimated). In-between values indicate to what magnitude the standard errors in the original regression have been inflated as a result of correlation with other independent variables. Exactly what value of VIF indicates a problem with multicollinearity is subjective, but a maximum value of 10 is typically used as a heuristic and any value above 5 should be investigated further (Hair *et al.*, 2009).

Table 4.8 presents the VIF for each of the four multivariate regression models and each specification within the four models. In general, there is not much cause for concern with multicollinearity in any specification. Some single-year binary variables in Models 2, 3, and 4 indicate a VIF between 2 and 5. In addition, when the dataset in Model 1 is reduced to only observations in central Sydney, VIF increases up to 4.3, most likely because there are fewer observations to use in statistical differentiation. Very recent years of commencement (notably 2010) have the highest VIF values.

Table 4.8. Variance Inflation Factor (VIF) for all independent variables of interest.

Model 1: Depth of Participation in NABERS	Spec. 1 (All Obs.)	Spec. 2 (All NLA Obs.)	Spec. 3 (Rated Hrs. Obs.)	Spec. 4 (Sydney CBD Obs.)
Two Certificates	*Reference*	*Reference*	*Reference*	*Reference*
Three Certificates	1.419	1.455	1.537	2.945
Four Certificates	1.314	1.349	1.389	2.667
Five Certificates	1.236	1.271	1.333	2.105
Six Certificates	1.351	1.422	1.513	4.300
Seven Certificates	1.321	1.383	1.472	3.025
Eight Certificates	1.417	1.477	1.574	4.246

Model 2: Two-certificate time effects	Spec. A (Year Binaries)	Spec. B (Conservative MD)	Spec. C (Moderate MD)	Spec. D (Liberal MD)
Benchmark 1999-2003	*Reference*			
Benchmark 2004	1.609			
Benchmark 2005	2.057			
Benchmark 2006	2.498			
Benchmark 2007	2.135			
Benchmark 2008	1.714			
Benchmark 2009	2.792			
Benchmark 2010	4.508			
Benchmark 2011	3.821			
Benchmark 2012-2013	2.770			
Mandatory Adopter		1.359	1.537	1.613
Voluntary Adopter		*Reference*	*Reference*	*Reference*

Model 3: Three-certificate time effects	Spec. A (Year Binaries)	Spec. B (Conservative MD)	Spec. C (Moderate MD)	Spec. D (Liberal MD)
Benchmark 1999-2003	*Reference*			
Benchmark 2004	1.625			
Benchmark 2005	2.066			
Benchmark 2006	2.726			
Benchmark 2007	2.178			
Benchmark 2008	1.866			
Benchmark 2009	3.217			
Benchmark 2010	4.955			
Benchmark 2011-2012	3.265			
Mandatory Adopter		1.337	1.623	1.819
Voluntary Adopter		*Reference*	*Reference*	*Reference*

Model 4: Four-certificate time effects	Spec. A (Year Binaries)		Spec. C (Moderate MD)	Spec. D (Liberal MD)
Benchmark 1999-2003	*Reference*			
Benchmark 2004	1.599			
Benchmark 2005	1.995			
Benchmark 2006	2.783			
Benchmark 2007	2.326			
Benchmark 2008	2.029			
Benchmark 2009	3.338			
Benchmark 2010-2011	3.818			
Mandatory Adopter			1.423	1.633
Voluntary Adopter			*Reference*	*Reference*

To understand what other variables are cross-correlated with these recent years, a correlation matrix was referenced. The highest correlations for a benchmark year of 2010 is the average days between certificates (-0.348) and green ownership (-0.202). Unsurprisingly, for recent entrants to NABERS, the time between certificates is effectively capped in order for the asset to appear in a database of certificates that is collected up until October 2013. Also, green owners are not likely to be included within the cohort of assets forced into NABERS Energy by mandatory disclosure in the BEED Act. These potential sources of bias could be considered, but the statistical model should have enough differentiation to distinguish between time effects and green ownership. If anything, the standard errors are inflated, but in the case of a benchmark year of 2010, time between certificates, and green ownership, the coefficients in the models are often statistically significant, so multicollinearity is only a concern if the degree of significance is of interest.

4.2 Conclusions

At the beginning of Chapter 3, two research questions were posed. The first asked how repetitive participation in NABERS Energy disclosures has influenced operational site energy consumption in existing office building assets. A second question asked whether energy performance outcomes associated with the first question are different between the panel of voluntary adopters and the panel of mandatory adopters. Following the gathering of data and estimation of statistical models, the findings associated with each of these questions are discussed below, followed by their limitations and implications for public policy.

4.2.1 The effect of NABERS Energy on site energy consumption

In answer to the first research question, the results of this study point to a consistent relationship between depth of NABERS Energy participation and operational energy efficiency in Australian office building assets. Initially, the more NABERS Energy audits undertaken by an asset, the more operational energy it conserves on average, all else equal. However, after the sixth audit, asset owners appear to reach an apparent post-intervention equilibrium energy consumption intensity, which, for the population in this study, measures approximately 430 MJ/m^2/year on average. Multivariate analysis reveals some differentiation within the population; large owners with green asset management strategies obtain marginally higher levels of energy efficiency, as do owners purchasing Green Power offsets regularly. This latter observation suggests Green Power offsets are a complement, not a substitute, to operational energy efficiency. Location is generally unimportant in relation to operational energy conservation, although assets in suburban and rural Queensland are less likely to reduce energy consumption than other assets in the database, most likely because of the unique property market conditions in Queensland described in Section 2.3.1. Regarding additional data examined in subsamples of the depth of participation models (Equation 3.6), specification two showed that asset size is not associated with energy savings and specification three showed that fixing the intensity of asset use had no effect on the results.

Additional models were needed to establish the robustness of the relationship between depth of certification and energy savings because of a high correlation between the year an asset commences NABERS Energy certification and the depth of its participation. Fixed time effects are only important at an asset's second NABERS Energy audit, when assets commencing in 2006 or immediately following the enforcement of mandatory disclosure are observed to reduce energy faster than assets commencing in other years. It was hypothesised that an increase in national attention regarding office asset energy consumption at these times could be responsible for the faster speed in reductions. These fixed time effects disappear as the population undergoes further certification.

Overall, the best predictor of operational energy savings was found to be an asset's benchmark energy consumption. Unsurprisingly, assets with higher benchmark consumption in the dataset are the ones with the greatest energy savings. This suggests the NABERS Energy certification process aids in reducing market variance in operational energy consumption by identifying outliers to asset managers. Descriptive statistics in Chapter 3 revealed a steady decrease in variance, most likely as a result of the ability for frequent audits to rein in the right tail of the distribution and maintain high performance.

One can also argue that the reduction of outliers is an outcome associated with the introduction of the NABERS Energy scheme. The only assumptions necessary are that the owners of energy inefficient outliers would not have undertaken a private energy audit without NABERS participation and that it was the audit that led to investment in efficiency. It is this logic that leads many scholars to concentrate on methods to increase participation in environmental disclosure schemes as opposed to optimising schemes in regards to environmental outcomes per participant (Borck and Coglianese, 2009). From this viewpoint, the savings attributed directly to NABERS Energy participation in the first multivariate model are best interpreted as additional savings *beyond* the process of simply undergoing an energy audit. For example, the NABERS method of producing star rating thresholds and providing a platform for open access to audit results go beyond what a private energy audit would produce. In addition, the collective participation of numerous asset managers in NABERS Energy simultaneously has likely produced a market for operational energy efficiency upgrades similar to the emergence of the Energy Service Company, or ESCO, in the United States documented by Hopper *et al.* (2007).

The formation of a market for office building energy efficiency is likely to be an important outcome associated with NABERS Energy certification. The best evidence that this market formed in association with NABERS Energy is the consistency of negative coefficients in the models testing for fixed time effects relative to the very first adopters. Only years associated with the Global Financial Crisis (2008-2010) hint at slower energy consumption improvements relative to the very first adopters of NABERS. Despite nearly all of these time effects being statistically insignificant, it is revealing that groups of adopters following the first users of NABERS achieved reductions in energy consumption at a faster pace on average through the first four certification periods.

Access to a developed market for operational energy efficiency helps explain the few observed fixed time effects as well as the mechanism for potential spillover effects measured in Figure 4.1. When the national attention of the office property market is tuned into energy efficiency, as happened in 2006, soon after NABERS was introduced nationally, and again in late 2010 when NABERS Energy became the tool for mandatory disclosure under the BEED Act, solutions for energy efficiency had been tested. Existing buildings interested in rapid operational improvements could access tested solutions without the need for innovation and learn from past experience via the market for asset energy efficiency. Only the motivation to improve operational energy efficiency is needed. National interest in responsible property investment in 2006 and the enactment of mandatory performance disclosure appear to provide asset managers with this motivation. The interpretation of the declining starting EUI seen in Figure 4.1 as evidence of spillover effects confirms the knowledge that the formation of these markets likely affects those with no interest in voluntary participation (Borck and Coglianese, 2009), though the pace of reductions in operational energy consumption from potential spillover effects is much slower than the pace of reductions attributed to NABERS Energy participation.

The dataset in this study was compiled soon after the enforcement of mandatory disclosure and it was observed that the population of assets having undergone only two certifications are likely to have commenced certification at a time when assets obtained faster operational energy reductions at the time of the second certificate than in other years (except 2006). Thus, the coefficient representing a participation depth of two certificates overestimates the “typical” energy reduction after two certificates. Since the two-certificate coefficient is a reference in the model, this means that energy reduction magnitudes of greater participation depth may be underestimated. However, the author uses “typical” cautiously because the introduction of mandatory disclosure may have permanently altered the behaviour of asset owners; perhaps the rate of energy conservation observed after the second certificate post-mandatory disclosure is a more appropriate representation of current practices. In this case, the coefficients for three-certificates and above may be more accurate in a mandatory disclosure environment, with a slight underestimation when applied to a voluntary disclosure environment.

Lastly, the overall justification for the introduction of NABERS Energy and mandatory disclosure is greenhouse gas mitigation. Policy targets are nearly always stated as a percentage reduction relative to an annual benchmark; for example, Australia's federal government has committed to an unconditional 5% reduction on greenhouse gas emissions measured in the year 2000 by the year 2020. Chapter 3 discussed why this study uses energy use intensity in the models instead of greenhouse gas emissions, so an assumption that greenhouse gases are proportional to energy consumption is necessary for this discussion[2]. Depending on how one accounts for outliers, potential sub-population bias and spillover effects, pre-NABERS Energy consumption averaged between 580 and 626 MJ/m^2/year for the entire asset stock. It was then argued in the univariate models that six NABERS Energy audits or more delivered an average asset stock consumption of 430 MJ/m^2/year, meaning a reduction in greenhouse gas emissions between 26 and 32%. The multivariate models attribute some of the reduction to green asset management strategies potentially unrelated to the presence of NABERS Energy, so it may be wisest to concentrate on the lower end of that range and conclude conservatively that NABERS Energy can be associated with an approximate one-quarter reduction in greenhouse gas emissions in those Australian office assets that have participated in the scheme.

This conclusion integrates well with the findings of Pacala and Socolow (2004), who argued that deployment of existing technology could reduce greenhouse gas emissions from energy consumption in the built environment by 25% relative to emissions in 2004. The rapid reductions seen in this study indicate that NABERS Energy, as implemented in Australia, may be an effective tool for introducing these existing technologies to the market rapidly. Pacala and Socolow proposed a 50-year timeframe for their 25% reduction. If the conclusion in this study is accurate, then stronger targets may be more appropriate for a 50-year timeframe. And perhaps Australia's 5% reduction target by 2020 across all sectors may also be too conservative since all the reductions measured in this study took place after the baseline year 2000.

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[2] In support of this assumption, Chapter 3 describes a high correlation between GHG emissions intensity and energy use intensity for those assets in the dataset with a consistent GHG accounting framework for NABERS Energy disclosure. But if there is an error in the assumption of a constant relationship between GHG emissions intensity and energy use intensity, the results in this study are likely to *underestimate* the degree of GHG mitigation. Fuel switching as a GHG mitigation strategy would result in similar, or higher, energy use intensity, but lower GHG emissions intensity.

4.2.2 The difference between voluntary and mandatory adopters

Three additional models run to ensure the robustness of the conclusion regarding the effect of NABERS participation answer the second research question regarding the difference between voluntary and mandatory adopters. While it was hypothesised that owners forced to disclose would be disinterested in energy efficiency from a strategic point of view, the evidence presented in this study suggests that despite their involuntary participation, mandatory adopters behave similarly to voluntary adopters in the relationship between depth of participation and operational energy savings. According to the conservative definition of mandatory adopters – those commencing on or after the date of enforcement – energy savings were higher after the second certificate relative to voluntary adopters, though this difference faded after the third certificate. More liberal definitions of mandatory adopter show that this lack of differentiation between voluntary and mandatory adopters is likely to hold true at the time of a fourth audit.

Given the early nature of this research, further data on mandatory adopters may change these initial conclusions. After three certificates, these models can only explain 18% of the variance in energy savings, a sign of attempting to measure a trend in the middle of transition to a new equilibrium. The study of the entire population found voluntary adopters continued to improve, on average, for over five years before reaching an apparent equilibrium. It is possible that as mandatory adopters reach their limits to improvement in the next few years that voluntary adopters may have better relative performance after five years. Additionally, it is possible that the introduction of mandatory adoption will affect the equilibrium of voluntary adopters. To re-establish the market differentiation that likely motivated their early participation, voluntary adopters may enter a second round of investment in asset energy efficiency. Future data collected from NABERS Energy audits will be needed to complete this narrative.

A small hint of this future narrative is provided by the more liberal definitions of mandatory adopter, which allowed a four-certificate model. However, the lack of sufficient data to run the conservative definition in a four-certificate model belies that all mandatory adopters obtaining four-certificates are assets entering NABERS Energy in the advance period before mandatory disclosure. These assets may be a distinct subpopulation of mandatory adopters and as such may behave somewhere in-between the typical mandatory adopter and the typical voluntary adopter. Nevertheless, the negative (but insignificant) coefficient for both the liberal and moderate definitions of mandatory adopter at the time of the fourth audit suggests the motivation of mandatory disclosure is sufficient to continue asset energy management practices in assets that did not seek to differentiate using NABERS Energy until mandatory disclosure was mooted as a likely reality.

4.2.3 Limitations

Despite a great deal of attention to robust model specifications, limitations with the methodology and data used in this study are unavoidable. Two limitations are discussed. One regards the interpretation of the NABERS Energy variables of interest: are they measuring depth of participation, or something else? Alternative interpretations are considered. The second limitation regards a non-random population sample and the bias that may result. While it is argued that any potential bias has little effect on the results, suggestions regarding application of the results are provided.

4.2.3.1 Alternative reasons for energy efficient investment

One concern with the study is whether the introduction of NABERS Energy simply allowed the public to measure investment in operational energy efficiency caused by something else. While it is only possible to speculate on what that “something else” may be, there is evidence to reject four possibilities. First, consider spillover effects, or the energy savings that would be obtained by non-participants as a result of technological innovation by voluntary participants. The tame magnitude of potential spillover effects (Figure 4.1) relative to the observed reductions attributed to NABERS Energy participation (Figures 4.1 and 4.2) discounts the possibility that the magnitude of observed energy performance improvement would have occurred as fast in the absence of certification. Perhaps spillover effects could catch up with the effect of NABERS Energy participation after a long time given the observed limit of participation effects after the sixth audit, but it is clear that NABERS Energy has sped up the process of greenhouse gas mitigation via operational energy efficiency in office assets.

A second possibility for “something else” is the growth of energy costs and introduction of a national carbon tax. Data obtained for the next two chapters show this potential cause to be weak. For example, in Sydney, the Property Council of Australia (2006a, 2010) recorded the median cost of energy in a Premium or A-Grade building grew in nominal terms from \$12.55/m^2/year in 2006 to \$16.78/m^2/year in 2010. But this growth calculated as a percentage of non-statutory operating expenses is only 17% to 19%, demonstrating that energy cost inflation is only marginally higher than that of other building management costs. The national carbon tax fixed at \$23 per tonne is trivial, adding approximately 3% to an average asset energy bill. Perhaps energy conservation is the most efficient avenue for asset managers to reduce their operational management costs, as is argued by Ciochetti and McGowan (2010) and Eichholtz *et* *al.* (2013), but a steady increase in variance among benchmark energy consumption as a function of year of entry into NABERS Energy (Figure 3.5) makes it difficult to accept that a wave of investment in operational cost management unrelated to the introduction of NABERS Energy is predominantly responsible for observed energy consumption improvements.

The third alternative explanation for the rise in operational energy conservation is the corporate social responsibility (CSR) "arms race" that took place amongst large Australian asset owners around the same time when NABERS Energy was introduced nationally in 2005. Recall that Bauer *et al.* (2011) praised Australian property funds as world-leaders in socially responsible property investment. Could national competitiveness in CSR be responsible for energy efficient outcomes observed via NABERS audits? The model results in this chapter controlled for ownership characteristics by including the owners identified by Bauer *et al.* as leaders in responsible property investment within a variable for green management strategy. The results indicate these green owners obtain higher operational energy reductions than owners deciding not to pursue a green management strategy, but the magnitude of the estimated green ownership coefficient belies only a marginal increase in energy efficiency over the average owner of an office asset in Australia. This suggests that the audit process and depth of participation in NABERS Energy affected the operational energy management of all asset owners, not just those in the CSR arms race.

The fourth alternative explanation concerns the rise of vacancy rates following the Global Financial Crisis. As Figure 2.8 indicates, at the end of this study period – when each asset's most recent certificate is likely to have been issued – office assets in the Sydney CBD are near their peak vacancy rates. However, vacancy is not likely affecting the results in this chapter for two reasons. First, the NABERS Energy assessment methodology clearly states vacant space is to be excluded from the Rated Area calculation during an audit (Department of Environment Climate Change and Water NSW, 2010). This reduces the denominator of the EUI calculation, offsetting any reduction in base building energy consumption as a result of vacancies. Thus, systematic auditor malpractice would be necessary for vacancy to be responsible for asset energy efficiency improvements. Second, the lack of a pattern of time effects associated with energy consumption reductions does not support a relationship between market cycles and the quantity of asset energy consumption reductions.

In addition to these four alternative explanations, this study provides weaker evidence related to other hypotheses. Undocumented state and local policy variations in most regions do not appear to have much measurable effect on operational energy variability. However other federal policies, such as the AusIndustry Green Building Fund or rating floors for government agency accommodation (see Section 2.2) cannot be decisively eliminated. Additional tests, such as a difference-in-differences model around a particular policy are needed to fully reject or confirm these hypotheses.

Economic variation is proxied via the location fixed effects variables, so the same logic regarding the effect of policy also applies to economic variations between markets. Investment variables associated with commercial office markets in Australia were presented in Section 2.3, noting very little variation between markets, with the exception of a boom associated with capital asset values in Brisbane CBD, Perth CBD and suburban Brisbane markets just before the Global Financial Crisis. This suggests the Queensland suburban boom may be responsible for the lack of observed operational energy conservation in that region, either through a lack of demand for energy efficiency or the possibility that the Brisbane suburban market is an emerging market with relatively young assets constructed to high standards of energy efficiency (thus are not likely to need investment in further energy efficiency once these new assets enter NABERS certification).

4.2.3.2 Sample Selection

Another concern relates to a biased sample, which is common in research on certification because the observed population is often self-selected and thus not fully random. However, this study is not as severely self-selected as the post-occupancy studies of LEED certification described in Chapter 1. The implementation of mandatory disclosure in Australia has helped to mitigate some of the self-selection bias, as has the comprehensive collection of every NABERS Energy certificate issued, but the scope of mandatory disclosure in Australia still falls short of requiring *every* office asset to certify. Table 3.6 in the previous chapter shows there is at least 50% of the national office stock (by floor area) that has yet to be multi-certified and thus self-selected out of this study. Regional discrepancies in sample coverage emerge, most likely because of the size threshold of 2,000 m^2 for mandatory disclosure. Smaller cities, such as Darwin (Northern Territory) and Hobart (Tasmania) do not have many assets subject to the regulation, so these states are underrepresented while Sydney (New South Wales) and Melbourne (Victoria) are overrepresented. The relative lack of significant locational effects in the multivariate model suggests this spatial bias may not have much effect on the results, although the variables for Darwin, Hobart and their states lack a clear interpretation because the markets had to be combined.

Thus, the analysis in this study covers primarily large office markets. But this restriction is slightly mitigated by the natural correlation between market size, energy consumption and greenhouse gas emissions. Large markets emit more greenhouse gas emissions. Furthermore, there is nothing to suggest that lowering the size threshold for mandatory disclosure would produce alternate results; the variable for building size was insignificant as a descriptor of energy savings in all models including it.

The 2,000 m^2 threshold is largely a product of the Australian federal constitution, which empowers the federal government to regulate statutory corporations, not individuals. Small assets are more likely to be owned directly by individuals outside of a corporate structure. This means that the sample is also likely to be biased towards corporate owners, but given the synergy between corporate ownership, building size, and energy consumption, this potential bias means the study addresses the most important contributors to greenhouse gas emissions in the office sector. To comprehensively test the effect of this bias, it would be necessary for an Australian state (which has the power to regulate individuals as property owners) to pass a disclosure law for small buildings, then use difference-in-differences methods to assess the impact of NABERS Energy on energy efficiency in small office assets and non-corporate owners. As of early 2014, no state is publicly discussing further disclosure regulations.

Statistical techniques to account for bias, such as a two-stage Heckman procedure (see Chapter 5 for a full description) were considered and some specifications of a selection equation using building size, location and owner characteristics were tested on specification two in the depth of participation model. None of these tests produced any changes to the results in Table 4.3. Anyone concerned with the potential for bias related to building size, location, and owner structure to alter the results presented in this chapter can restrict application of these results to markets with large assets owned by corporate entities.

4.2.4 Implications for Policy

In Chapter 1, the context of policy effectiveness was established using Borck and Coglianese (2009), who proposed the following equation in regard to the effectiveness of a voluntary certification scheme:

$$Effectiveness = \begin{matrix} Number\ of \\ Participants \end{matrix} \times \begin{matrix} Effect \\ per\ Participant \end{matrix} + \begin{matrix} Spillover \\ Effect \end{matrix} \tag{4.2}$$

For this discussion, in which a voluntary disclosure scheme became mandatory, it is best to re-write equation 4.2 to enable comparison between participants and non-participants:

$$Effectiveness = \frac{Number\ of}{Participants} \times \frac{Effect}{per\ Participant} + \frac{Number\ of}{Nonparticipants} \times \frac{Spillover}{Effect} \quad (4.3)$$

The policy being implicitly tested in this study is the BEED Act, which introduced mandatory disclosure of NABERS Energy ratings to all large office assets in Australia. As such, the important action associated with the policy is to convert non-participants into participants[3]. Effectiveness is defined as operational energy consumption reductions, which proxy the mitigation of greenhouse gas emissions. This creates two questions of interest for policymakers, one of which was a key question in this study. First, does effect per participant change when non-participants in the voluntary scheme are forced to disclose? Second, how does effect per participant compare with the spillover effect?

Evidence from this study argued that there is no measurable difference between mandatory and voluntary adopters in regard to effect per participant. Initial energy efficiency outcomes from Australian assets required to disclose energy performance are similar to assets that chose to voluntarily disclose performance prior to the mandate. There is some evidence that mandatory adopters are implementing operational energy efficiency faster than voluntary adopters. Most likely, this is because voluntary adopters faced higher risk in reducing energy consumption while developing a market for energy efficiency; later adopters benefit with lower risk and a mature market as a positive externality. After three certification periods, there is no difference between mandatory and voluntary adopters. Policymakers must keep in mind that early voluntary adopters continued to reduce operational energy consumption for five to six years after an initial benchmark certificate, so caution is advised in regard to long-term outcomes for mandatory adopters since this study is limited to measuring effectiveness in the middle of a transition to post-certification equilibrium.

With no difference in effect per participant at this stage in the implementation of mandatory disclosure, attention turns to the comparison between effect per participant and spillover effects. Figure 4.1 presented an attempt to measure spillover effects. Although this method comes with uncertainty – the proposed spillover effects could be measuring sub-sample bias – it clearly shows that effect per participant expectations (orange area) is much greater than the estimated spillover effects (brown area). The change in effectiveness as a result of mandatory disclosure converting non-participants into participants is:

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[3] This is strictly true only for the population of assets subject to the BEED Act. Non-participants remain (see Table 3.6) post-enforcement because of exemptions (mainly small assets) and assets not typically in the process of lease or sale such as owner-occupied buildings.

$$\Delta Effectiveness = \begin{matrix} Number\ of \\ Nonparticipants \end{matrix} \times \left(\begin{matrix} Effect \\ per\ Participant \end{matrix} - \begin{matrix} Spillover \\ Effect \end{matrix} \right) \tag{4.4}$$

Since effect per participant is much greater than the estimated spillover effect, it can be concluded that the BEED Act is currently succeeding in its objective to reduce greenhouse gas emissions from operational energy consumption. However, there is evidence that spillover effects were growing over time and may eventually deliver the same effectiveness as mandatory disclosure, so perhaps a better conclusion is that the BEED Act has been successful at delivering a *faster* transition to energy efficiency. One example of this faster transition was the discussion in section 4.2.1 indicating 50-year greenhouse gas mitigation targets for the built environment could be met in approximately six years based on the estimation of effect per participant in post-NABERS Energy intervention equilibrium.

Assessing the outcomes of the BEED Act in this context is important because similar mandatory disclosure policies have been considered in New York (Kontokosta, 2013) and enacted in California. European states are considering the implications of switching from asset ratings (confusingly called Energy Performance Certificates) to performance ratings (called Direct Energy Certificates) in their statutory responses to mandatory disclosure under European Union Directive 2002/91/EC (Fuerst *et al.*, 2013). The presence of a spillover effect in relation to voluntary performance disclosure schemes opens up the debate of whether such regulation is necessary; for example, spillover effects may be sufficient to meet those 50-year greenhouse gas mitigation targets in 50 years. Based on the evidence in this study, the effectiveness of mandatory performance disclosure as implemented in Australia is preferred if a more rapid decrease in energy consumption is desired.

Policymakers should understand that the framework for success in Australia was not only the structure of the BEED Act, but also the context of a pre-existing voluntary scheme that was widely used. The creation of a market for energy efficiency was discussed as a contributing factor to the observation of why mandatory adopters could outpace voluntary adopters in early returns to energy conservation. One can expect that attempting to mandate a disclosure system that has little or no voluntary participation may lead to a longer lag between implementation and measurable success, given the need to develop a market for energy efficiency upgrades in that scenario. In addition, Chapter 2 discussed a number of coordinated federal policy responses to operational energy efficiency, such as aspirational NABERS Energy rating floors for public service accommodation procurement and financial incentives for energy upgrades, that are only considered in this research if their incidence differed by state. Future research will seek to identify individual assets that benefit from these alternative policies and attempt to control for their unique effects.

In regard to forecasting the outcomes of a mandatory disclosure policy, the best predictor of performance improvement was pre-intervention energy use intensity (EUI) for buildings entering the disclosure programme. Study of the voluntary adopters revealed a post-intervention equilibrium of 430 MJ/m^2/yr. for the Australian asset stock on average, indicating technological or market limits to investment in operational energy efficiency. The gap between this post-intervention equilibrium and the current performance of the stock represents a very rough estimate of the potential energy savings from successful mandatory disclosure policy. Therefore a mandatory disclosure policy will have the greatest impact in markets with high average EUI pre-intervention.

4.3 Next Steps

Overall, this chapter concludes that the introduction of NABERS Energy to mitigate greenhouse gas emissions associated with commercial office assets has been successful at motivating private investment in operational energy efficiency. Mandating the tool to increase the level of participation does not appear to have dampened the motivation to invest in energy efficiency in Australia.

This thesis now shifts to consider the market transformation that has motivated private investment in energy efficiency. The next two chapters look at a subsample of the assets studied in these two chapters to understand better how energy efficiency is valued in the market for office space. Rental income from tenants is the key income stream for office asset owners and investors. Theory discussed in Chapter 1 argued that tenants should be willing to pay higher rent for energy efficient office space. Using the database of NABERS Energy certificates collected for this study, the next two chapters test this theory to investigate whether rent prices in Sydney are a function of an asset's NABERS Energy rating at the time of lease.

Chapter 5

Sydney Lease Market Effects: Data and Methodology

Having demonstrated a strong link between depth of participation in NABERS Energy and operational energy efficiency, this research turns to examine the resulting property market transformation. As was seen in Chapter 1, the incidence of energy efficiency premiums in the property market has been of much greater interest to property scholars. Early studies, such as those from Miller *et al.* (2008), Eichholtz *et al.* (2010), and Fuerst and McAllister (2011b) support the theory that green and energy efficient office assets "pay off" to those who develop and invest in them (Warren-Myers, 2012). Higher investment value creates the incentive for further development of green assets, which drives the transformation to a more energy efficient and environmentally friendly property market.

But the empirical literature concentrates only on the top of the property value chain: investors, developers, and owners. By using asset-level data almost exclusively, a knowledge gap exists as to how this value is created. Do office tenants pay higher rents for energy efficient accommodation? Do tenants sign longer lease contracts? Do purchasing investors reduce the capitalisation rate for a green asset because its income stream appears less risky than non-green assets? Do owners of energy efficient assets face fewer costs for tenant churn? From a property valuation perspective, Warren-Myers (2012) outlines a comprehensive list of theoretical benefits accruing to owners and occupants of green property assets (see Table 1.2). This chapter begins a thorough investigation into just one of these ownership benefits – higher rental income per tenant. Hence this chapter seeks to answer the first question posed above. Are rent bids positively associated with asset energy efficiency?

Using the NABERS Energy data gathered for the last two chapters along with additional data extracted directly from lease contracts, this study builds a comprehensive hedonic model of rental transactions in central Sydney to test the hypothesis suggested by the literature that tenants pay rents as a function of NABERS Energy ratings, among other things. Table 1.2 presented theoretical benefits that tenants would be willing to pay for in an energy efficient building, including enhanced corporate reputation and reduced operating costs. Numerous existing studies assume that rental income premiums found in aggregate at the asset scale are the result of tenants paying higher rents for energy efficient accommodation (for example, Reichardt *et al.*, 2012, Eichholtz *et al.*, 2013). But Section 1.2.3 argued that asset-scale rent premiums could also arise from occupancy rates, occupant distribution, market timing, and valuation bias.

Newell *et al.* (2011) used central Sydney as one of three commercial office markets in the lone asset-scale investigation of energy efficiency price premiums in Australia. They found a similar trend in Sydney green property prices and rents as was observed in the United States, arguing that net rental income is positively correlated with NABERS Energy ratings. This study seeks to eliminate the influence of occupancy and market timing[1] by constructing a model to test directly whether tenants pay premiums for lease contracts in energy efficient buildings.

To test whether tenants pay higher rent, this study changes the scale of transaction modelling from the asset scale to the tenancy scale. The first section of this chapter describes the data collection process for office lease contracts in central Sydney as well as the collection of a number of control variables for the model specification. Section 5.2 describes the data. Section 5.3 constructs the hedonic model using face rental rates as the dependent variable for all valid observations. Section 5.4 considers the possibility that rental incentives cannot be controlled via fixed time effects and constructs a model using effective rental rates as the dependent variable and specifies a test for subsample bias because effective rent can only be calculated for just over half the lease observations. A brief summary of all model specifications is provided in Section 5.5. Chapter 6 presents and discusses the results.

5.1 Data

For this chapter, data from NABERS Energy certificates collected in Chapter 3 for the study on environmental effectiveness are combined with observations of lease contracts to investigate the market demand for energy efficient office accommodation. Additional data on fixed asset characteristics, such as building age and subjective quality rating, are collected as additional control variables. Two approaches at representing spatial submarkets are considered, the traditional Property Council of Australia boundaries and a finer delineation within these boundaries. Binary variables representing fixed time effects are also included in the model specification. Table 5.1 summarises all the variables captured in the lease database.

Before describing the data in detail, it is worth revisiting why Sydney has been chosen for this study. Section 2.3.2 describes how Sydney is a large and openly competitive property market. Only 7% of the lease transaction database constructed in this chapter is for accommodation let to

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[1] Newell *et al.* observed rental income at the asset scale. Valuation bias is not likely to be an influence on their results because asking rents were excluded.

government tenants. This bias is “helpful” because it reduces the influence of aspirational government accommodation energy rating floor policies (Section 2.2.1) to better understand how asset energy efficiency is traded in a competitive open market. In addition, the registration of lease contracts in central Sydney is common, enabling public access to original lease contracts.

Table 5.1. Data compiled for the lease database (N=673). See referenced section for more detail on each metric.

Category	Variable	Section	Units
Rent Payments	Face Rent	5.1.2.1	A\$/m^2/year
	Percentage Rent Review		% increase & date of increase
	Market Rent Review		date
Operating Expenses	Net Lease	5.1.2.2	Binary Variable (1=yes)
	Semi-Gross Lease		Binary Variable (1=yes)
	Estimated Annual Payment		A\$/m^2/year [A]
Signing Incentives	Incentives Observed	5.1.2.6	Binary Variable (1=yes)
	Total Incentive		A\$ [B]
	Structure of Payment		A\$/month, for all months in term [B]
Lease Descriptors	Tenancy Area	5.1.2.1	m^2 NLA
	Agreement Date	5.1.2.3	date
	Commencement Date		date
	Termination Date		date
	Lease Term		months
	Option(s) to Renew		Binary Variable (1=yes)
	Bank Guarantee	5.1.2.5	months
Asset Descriptors	NABERS Energy Stars	5.1.1	stars (excluding Green Power)
	Audited Energy Consumption		MJ/m^2/year
	Asset Size	5.1.3.1	m^2 NLA
	Asset Age		Years between construction and lease
	Asset Quality	5.1.3.2	Binary Variables (1=yes) [C]
Location Effects	PCA Submarket	5.1.3.3	Binary Variables (1=yes) [D]
	Smaller Submarket		Binary Variables (1=yes) [E]
	Distance to Train Station		metres
	Average Floor Height	5.1.2.4	storey
Fixed Time Effects	Commencement Half-Year	5.1.4	Binary Variables (1=yes) [F]

[A] Value captured for net leases only

[B] Value captured for N=342 observations where signing incentives are observed; N/A otherwise

[C] Four Binary Variables are produced, one for each quality rating: Premium, A, B and C

[D] Four Binary Variables are produced, one for each PCA submarket: City Core, Western, Midtown, and Southern

[E] Nine Binary Variables are produced, one for each smaller submarket: Wynyard North, Wynyard South, Lower George Street, Upper George Street, Darling Harbour, Circular Quay, Chifley Square, Martin Place, and Hyde Park

[F] Ten Binary Variables are produced, one for each half-year period between January 2007 and December 2011

5.1.1 Energy Rating and Consumption

The complete database of NABERS Base Building Energy certificates described in Section 3.1 is used to represent the energy performance of each individual asset. Only a small subsample of the complete NABERS Energy database is needed to cover central Sydney. In total, 164 assets within the boundaries of central Sydney have obtained at least one Base Building NABERS Energy certificate. Note that there is no requirement in this part of the research for an asset to be multi-certified in order to be included for consideration in the models for lease market effects.

The key purpose of the NABERS Energy database in this chapter is to match each lease contract with the NABERS Energy certificate available at the time the contract was signed. To estimate an "issue date" for each NABERS Energy certificate, each certificate was assumed to be valid for one year, so the issue date is calculated to be 365 days prior to the expiration date. Following the processing of the lease transaction data (see Section 5.1.2 below), 102 of the 164 office assets in the NABERS Energy database for central Sydney have at least one lease transaction observation after becoming certified.

The NABERS Energy database constructed in Chapter 3 only includes Base Building Energy certificates and excludes a small number of Whole Building Energy certificates. In central Sydney, the Whole Building scope is rarely used because nearly all multi-tenanted buildings have the required sub-metering in place to create a split between Base Building and Tenancy scopes. Including the Whole Building ratings for this study would only result in the inclusion of one lease contract in one additional asset. Base Building NABERS Energy certificates neatly mimic the operational energy costs that are negotiated during a lease transaction, so their scope is most appropriate for the rental bid of a prospective tenant. Furthermore, Whole Building (and Tenancy) ratings contain information on the energy consumption of existing tenants that may not be relevant to prospective tenants. Hence, as in Chapter 3, only Base Building certificates are included in this part of the study.

The star rating and the raw energy consumption from each certificate are used to estimate energy efficiency rent premiums. In Chapter 3, only raw energy consumption was argued to be consistent across all of Australia. However, in a single market, the star ratings can also be consistent as long as the benchmarks used to calibrate star ratings have not changed. According to Bannister (2012), the calibration equation for New South Wales has not been altered since an adjustment in 2000 so the necessary assumption of consistent benchmarks appears to be valid for the time period of the lease database (2007–2011). As a result, the study will test the effect of star rating thresholds on rental rates and in a separate specification test the effect of raw energy consumption. Star ratings used in the model will exclude Green Power offsets to remain in-line with the rating that tenants are exposed to under mandatory disclosure in the BEED Act.

5.1.2 Lease Transactions

Lease transaction data in central Sydney is sourced from a sample of lease contracts issued with a permitted use of "commercial offices" and registered between January 2009 and July 2011 on a land title with the New South Wales Department of Land and Property Information. Although it is not mandatory, most commercial lease transactions are registered in Sydney. However, commercially available lease transaction data was not available in sufficient resolution for robust modelling, so the author decided to extract the data for this study directly from the original contracts. RP Data, a local data provider that acquires lease contracts directly from the NSW Department of Land and Property Information kindly supplied the author with 1,526 scanned copies of original lease contracts for office accommodation in the Sydney central business district (as defined by the Property Council of Australia). Because the execution dates for these leases are spread out between 2004 and 2011, the fraction of Sydney office lease transactions observed in this sample is unknown. Section 5.3.7 below attempts to calculate the fraction of total office space in Sydney (by floor area) observed in a lease transaction.

As explained in the previous section, leases in assets that had not received a NABERS Energy certificate at the time of lease agreement are removed. The date of agreement on each of the 1,526 leases was extracted from each lease contract and matched with the issue dates calculated for all NABERS Energy certificates issued to the asset owner. If the lease contract was signed at least one day after the issue date of a particular certificate, that certificate was eligible to represent the energy performance of the asset at the time of lease. In the case of many certificates issued prior to the lease, the chosen certificate to represent energy performance at the time of lease is the one with the fewest days between the issue date and the date of lease agreement. At the end of this process, it was determined that 937 lease contracts in the sample represented accommodation in a NABERS Energy-rated asset at the time of lease agreement.

Data on the contract terms of these 937 leases were extracted manually and entered into what will be referred to as the “Sydney lease database” or “lease database”. The research question being addressed with this lease database is the relationship between rental payments and energy efficiency so all information that is likely to influence the rental rate specified in the contract is collected. The data extracted from each contract includes: annual face rent, tenancy floor area, operating expense liability structure (net or semi-gross lease), first year operating expense estimations (available for net lease contracts only), commencement date, term length (excluding options to renew), lowest floor of the tenancy, building address, tenant bank guarantee (security deposit) amount, management firm, and any relevant signing incentives. These data and the methods used for systematic recording are explained in more detail later in this section.

Following the extraction of these data, 123 of the 937 lease contracts are excluded as a non-market rent transaction. The presence of any one of three scenarios described below results in the exclusion of a contract as a non-market lease. First, some contracts explicitly state that face rent does not represent market value. Two examples are a sub-lessee that assumed an existing contract negotiated years before and a tenancy that was known to suffer from unusual noise pollution within the asset. Second, non-market rental rates can be the result of a binding clause in a prior lease agreement. This indicator of a non-market lease was the most common among the 123 excluded non-market leases. The archetype of this scenario is the exercise of a tenant option for a new lease term where a hard ratchet clause determines face rent instead of a market rent review. Third, non-market rental rates are indicated when a market rent review date is scheduled within one year of lease commencement. This short time belies the likely inclusion of a signing incentive within the initial face rent, otherwise the owner and tenant would not likely agree to a costly rent review process so soon after commencement.

Further exclusions from the lease database are made based on erroneous classification of lessee business activities, missing data and duplicated contracts. Fifty-seven of the remaining 814 leases were excluded on the grounds that they were not being used for commercial office space. Despite the permitted use in these 57 lease contracts being listed as “commercial offices”, it was obvious from reading the lease that the tenant intended to use the space for retail outlets, fitness centres, health clinics, restaurants or hotel accommodation. Missing data resulted in the exclusion of an additional 68 lease contracts; face rent at commencement is not disclosed on 40 contracts and 28 lease contracts are excluded for missing a critical control variable such as tenancy area or the structure of operating expense payments. Finally, to ensure each observation is independent, 26 lease contracts are condensed into 10 unique observations because of identical terms in lease contracts for multi-floor tenancies where separate contracts were procured for each floor leased.

In total, 673 observations in NABERS-certified buildings make up the complete lease dataset. Although the leases were registered between January 2009 and July 2011, agreement dates vary between January 2007 and July 2011. The following subsections describe the systematic data extraction procedure for rental rates and key control variables in more detail.

5.1.2.1 Annual Face Rent & Tenancy Area

Each office lease in Sydney specifies a rent payment in Australian dollars that must be paid in equal monthly instalments beginning on the commencement date as consideration in exchange for a leasehold interest. This amount is referred to as the annual face rent. In an open-market rent negotiation, the lump sum representing the annual face rent is calculated using an area-normalised figure, annual rent per square metre of net lettable area (NLA), multiplied by the NLA of the tenancy. Not only is rent per square metre more useful in property comparison and market analysis, but it is also the figure that is negotiated during a lease transaction in Sydney. Thus, the key value collected for the lease database to represent face rent is annual rent per square metre of NLA at the commencement of the lease.

The typical lease is a multi-year contract with annual rent reviews occurring on the anniversary of commencement. For office accommodation in Sydney during the period of the lease database, there are only two types of rent reviews observed: market and fixed percentage. A market rent review involves a professional estimate of open-market rent, which becomes the new rent amount on the rent review date. Such reviews are often subject to a "hard ratchet" clause stating that a market rent review cannot decrease the rent from the previous rental year. More common is an annual fixed percentage review, which increases the nominal face rent paid in the previous year by a fixed amount (usually 4%) for the next rental year. In the rental database, the rent review structure is captured from commencement until the end of the lease.

For tenancy areas, the Property Council of Australia (2008b) publishes a thorough guide to measurement of NLA. This allows a high degree of standardisation in the calculation of tenancy areas that are captured for the lease database. In a few lease contracts, NLA had yet to be formally surveyed using this method, so estimates described in the agreement are captured for the database.

5.1.2.2 Operating Expense Liability Clause & Estimated Operating Expenses

The Sydney office market contains two lease structures – net and semi-gross[2] – that specify the party responsible for payment of the tenant's proportion of common area operating expenses. More specifically, a Sydney lease contract specifies liability only for the base amount of operating expenses, which are costs per square metre of NLA for the first year of a lease contract. The type of contract offered is constant within each asset; there are no examples of a mixture of net and semi-gross lease contracts in the same asset. In both lease structures, tenants are invariably responsible for increases above the base amount in subsequent years as well as utility bills (mainly tenant equipment plug loads) within their own tenancies. In a net lease, the tenant is responsible for a proportionate share of estimated base year common area operating expenses as a recurring monthly payment. A semi-gross lease indicates the base year common area operating expenses are included in the initial face rent, so the owner pays the tenant's proportion of the base amount of operating expenses. Because net and semi-gross tenants are identically liable for

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[2] In Sydney, semi-gross leases are occasionally referred to as "gross" leases in the text of a contract (e.g. Figure 5.1). The term "semi-gross" is used in this research for readers unfamiliar with Australian commercial property markets to avoid misunderstanding when read in a global context. For example, "gross" leases in the United States are synonymous with the "full service" lease, wherein an owner is liable for the payment of all operating expenses, not just the base year amount of common area expenses as is the case in a Sydney semi-gross lease.

increases in common area operating expenses above the base year, the relationship between net and semi-gross face rents in a perfectly competitive market can be expressed as follows:

$$\frac{SemiGross\ Face\ Rent}{m^2\ NLA} = \frac{Net\ Face\ Rent}{m^2\ NLA} + \frac{Base\ Year\ Common\ Operating\ Expenses}{m^2\ Whole\ Building\ NLA} \qquad (5.1)$$

For the lease database, the face rent from each contract is identified as either net or semi-gross using a binary variable for both classifications.

For net leases, estimated base year operating expenses associated with each lease contract was also captured for the lease database. In nearly all cases of semi-gross leases, is not possible to obtain an estimate of base year operating expenses because these costs are included in the face rent. In practice, the base year amount for a semi-gross lease is not determined until the end of the first rent year, so it is impossible to specify in a pre-occupancy lease agreement. However, most net leases include an estimate of base year operating expenses because tenants in a net lease must pay an instalment of base year operating expenses along with their first rent payment. In the event of a missing base year operating expense estimate in a net lease, the amount from another lease in the same asset commencing in the same financial year is used as the estimate.

5.1.2.3 Rental Term & Options to Renew

Commencement and termination dates for each lease contract are captured in the lease database. While commencement dates are unambiguous, there is subjectivity regarding the termination date because some lease contracts pre-negotiate multiple terms with an option offered to the tenant for renewal at the end of each term. The approach taken in constructing this lease database is to determine the termination date as the day prior to the date of the first option to renew. If the tenant exercises its option, the new rental rate is invariably set via a market rent review, so there is little financial benefit to the tenant of an option to renew besides the right to remain in the same premises. Nevertheless, the presence of options to renew is captured in the database as a binary variable.

The length of a lease term is calculated from the lease as the number of months between the commencement and termination date. For leases that include option terms, the length of a lease term is calculated as the number of months between the commencement date and the first option date, for reasons explained above. The lease term, in months, is often stated explicitly on each lease as it is the number of rent payments that must be made during the lease. Fractional months are recorded as a decimal in the same manner as the corresponding fractional rent payment is calculated in the lease contract.

5.1.2.4 Micro-location Indicators

When reading the lease contracts, it became obvious that rental rates are a function of the micro-location of each tenancy. In particular, the height of each tenancy within the asset is an important factor. Figure 5.1 provides a good example of a lessor determining face rental rates as a function tenancy height. Therefore, the floor level of each tenancy was recorded in the lease database. For multi-floor tenancies, the area-weighted average floor level of the tenancy was calculated to represent that particular tenancy, with the number of floors captured in a separate variable.

Rental Schedule as at 1 January 2007

Level	Nominated Starting Gross Rent
Level 22	$670
Level 23	$675
Level 24	$680
Level 25	$685
Level 26	$690
Level 27	$695
Level 28	$705
Level 29	$710

Figure 5.1. Example of rental rates as a function of tenancy level. Source: Sydney registered lease dealing AD822219.

Other possible micro-location effects on rental rates were not possible to extract systematically from the sample of lease contracts. Sydney Harbour views are one example. Partial-floor tenancies on the same floor in assets with views to Sydney Harbour would be expected to vary depending on whether the tenancy was located in a position to capture those views. However, there was insufficient information provided in the lease contract to identify tenancies with such views. In addition, the potential for rental discounts resulting from unusual noise pollution (i.e. a tenancy located directly below a mechanical plant room) or other undesirable micro-location effects was typically unobservable. In instances where a lease was explicit that a rental discount was given because of an unusual micro-location effect, such as noise, the lease was eliminated from the database on the basis that the rent did not represent market value. Lastly, the quality or estimated value of any pre-existing fit-out left by a previous tenant was not observable.

5.1.2.5 Bank Guarantee (Security Deposit)

For security against tenant default, Sydney lessors require a specified number of full monthly rental payments be deposited by the lessee in a bank account that can only be drawn down by the asset owner. The amount deposited is called a "bank guarantee" in every lease contract. In the event of tenant default, the owner is given the right to use these funds in collecting debts. If a tenant does not default, the bank guarantee is returned to the tenant after the termination date once all debts have been cleared.

The amount of a bank guarantee is based on an agreed multiple of monthly rental and operating expense payments. The multiple representing the number of months is negotiable and varies between tenancies in the same asset. High quality tenants at low risk of default, such as government agencies and wealthy multinational corporations, are typically offered a lease without any requirement for a bank guarantee (zero months of payments). On the other hand, tenants deemed to be a high default risk are asked to provide large bank guarantees, such as a full year of payments, and required to increase the bank guarantee following any rent review that results in increased monthly payments. Three to six months of payments is an average requirement for the bank guarantee, depending on the asset. Low-quality assets usually require three months; high-quality assets usually require six. Because the size of the bank guarantee provides a proxy for the subjective measure of tenant default risk, the number of months of rental payments required for the guarantee is captured in the lease database.

5.1.2.6 Signing Incentives

In a slow or declining market, Sydney lessors offer a financial incentive to attract prospective tenants. This incentive payment can be calculated in many ways, but industry reports and leases often express signing incentive amounts as a percentage of the total consideration paid to the owner (based on the initial face rent) as such:

$$Incentive \ = Incentive\ percentage\ \times \frac{Annual\ Face\ Rent}{m^2} \times Tenancy\ NLA\ \times Lease\ Term\ (yr) \qquad (5.2)$$

The incentive percentage can be a significant portion of the total consideration. For example, in the post-Global Financial Crisis market, the typical incentive percentage in central Sydney was reported to be as much as 30% (Colliers International Research, 2011).

The payment structure of signing incentives varies between lease contracts. The three most common methods, in no particular order, are (1) a rent payment holiday from commencement until the signing incentive amount is exhausted; (2) a lump-sum contribution to expenses incurred by the tenant during relocation and fit-out of the office space; or (3) an equal monthly rent discount over the entire lease term[3]. Often, multiple distribution methods are offered; for example, a tenant that does not exhaust its signing incentive offered as a fit-out contribution (2)

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[3] In this third distribution option, a monthly rent discount is calculated as the signing incentive amount divided by the total number of monthly lease payments. The calculated monthly rent discount remains fixed in nominal terms and does not change during a rent review.

is allowed to apply the remaining funds to a rent payment holiday (1). In many cases, the tenant chooses its preferred distribution.

Only 340 of the 673 leases disclose what appear to be full incentive payments in the text of the lease. Because lease incentive payments can be large, it is common for Australian building owners to obfuscate incentives given to tenants, declaring them "confidential information" or simply omitting them from a registered lease contract. Thus, it is impossible to be confident that a lack of incentives in the registered lease contract indicates no incentives were paid. According to most market analysts, such as Colliers International Research (2011), and many advertisements for Sydney office space, such as Figure 5.2, incentives are usually described as a fixed market effect that varies over time. However, their potential use to create a shadow rental price[4] cannot be ignored. Hence the quantity of all known signing incentives and timing of incentive payments are recorded in the lease database for the 340 properties that appear to disclose full incentives. These data will later be used to model an "effective rent" paid by Sydney tenants.

Figure 5.2. Example of a lease advertisement referencing a market incentive.

Other types of signing incentives, such as complementary vehicle parking, were not observed. This is not to say that incentives outside of the three forms of rent assistance described above do not exist in the Sydney market, but rather that only rent assistance incentives are disclosed on registered lease contracts. In the event that complementary vehicle parking is offered as an incentive, it would be set out in a separate parking contract that is not registered along with the

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[4] For example, it cannot be rejected that rental price negotiation occurs in both the agreement of an incentive percentage and the negotiation of a face rent amount.

lease. This separate contract may not even be between the tenant and landlord. In many assets, a third-party leases all vehicle parking spaces from the landlord, meaning that tenant parking contracts are typically negotiated with this third-party operator.

5.1.3 Fixed Asset Statistics

Following the capture of data from 673 lease contracts in the final lease database, external data sources were consulted to provide additional descriptive data for the 102 unique office assets. Information on asset size, asset age, asset quality, and macro-location within central Sydney are captured for each lease transaction from a variety of sources.

5.1.3.1 Asset Size & Asset Age

The RP Data Cityscope database for central Sydney is used to obtain asset size and asset age. Asset size is measured as net lettable area (NLA) in the entire asset. Since assets must be 75% office space in order to be certified by NABERS as an office building, there is little concern over variation in the size of non-office space in multi-use assets. Asset size is considered fixed over the entire study period, so each lease in the same asset is assigned an identical asset size.

Asset age is recorded as the number of years from construction to the signing date of each lease. The variable of years since construction is used to include information on asset vintage. Besides the date of construction, the RP Data Cityscope database also provides a “last renovation” year. However, the asset quality rating explained below includes much of the information that a variable representing years since renovation would add to the model, such as the quality of mechanical services and other technologies that could have been upgraded post-construction.

5.1.3.2 Asset Quality

Chapter 2 described Australia’s comprehensive guide to grading the subjective quality of an asset. The Property Council of Australia conducts occasional audits of quality in major markets – the most recent audit in Sydney was in 2010 – but does not publish results publicly. However, audited quality grades are widely known among real estate agents and published in agency reports. This study extracted asset quality grades for each of the 102 assets from a wide variety of agency reports (such as Colliers International Research, 2011). There are no D-grade assets in the lease sample. Like asset size, a quality rating is considered fixed for each asset, so all leases in the same asset are assigned the same quality rating regardless of the commencement date.

5.1.3.3 Macro-location

Although all assets in the lease database are located within a single urban market, there are likely to be fixed location effects – prestigious submarkets, for example – associated with spatial distribution within central Sydney. One basis for modelling these fixed effects is to use the boundaries of submarkets defined by the Property Council of Australia (see Figure 3.3). All 102 assets in the lease database are located within four of these submarkets: City Core, Midtown, Western Corridor, and Southern. These four submarkets will be referred to as the “PCA submarkets”.

Using ArcGIS software, a finer delineation of submarket boundaries was created. Starting with the PCA submarket boundaries, the spatial distribution of the 102 office assets was analysed within these boundaries. Clusters of assets were used to split some PCA submarkets into smaller submarkets. Knowledge of asset quality groupings, market experience and local geography confirmed the appropriateness of spatial differentiation amongst the smaller submarkets. Figure 5.3 presents a map of the smaller submarkets, with key rail transportation infrastructure also displayed. The most popular PCA submarket, City Core, was divided into four smaller submarkets named after well-known Sydney landmarks: Circular Quay, Chifley Square, Martin Place, and Lower George Street. The PCA submarket Midtown was divided into two: Hyde Park and Upper George Street. The Western PCA submarket became three smaller submarkets: two based around a popular central train station - Wynyard North and Wynyard South – and one based on the redeveloped Darling Harbour precinct. The Southern PCA submarket remained unchanged. Recall that none of the 102 assets in the lease database are located in the PCA submarkets of Walsh Bay (currently a redevelopment area) and the Rocks (a historical district), so these are also left unchanged in Figure 5.3. In the remainder of this study, the finer delineations of submarket boundaries are referred to as “smaller submarkets”.

In the lease database, both submarket scales are captured. For the PCA submarkets, each lease is coded with a binary variable equalling one if the asset is in the submarket and zero otherwise. A second set of binary variables is created for the smaller submarkets. These variables assess an unobserved range of fixed effects associated with the spatial location of the asset within central Sydney.

Not all fixed location effects are unobservable. Accessibility to public transport, specifically high-frequency heavy rail transit has been linked with rental rates (Kok and Jennen, 2012). In this study, the walking distance to the nearest train station marked on Figure 5.3 is calculated for each of the 102 assets using the New South Wales Transport Info trip planner (http://www.131500.com.au). The lease database includes the distance to the train station in metres for each lease.

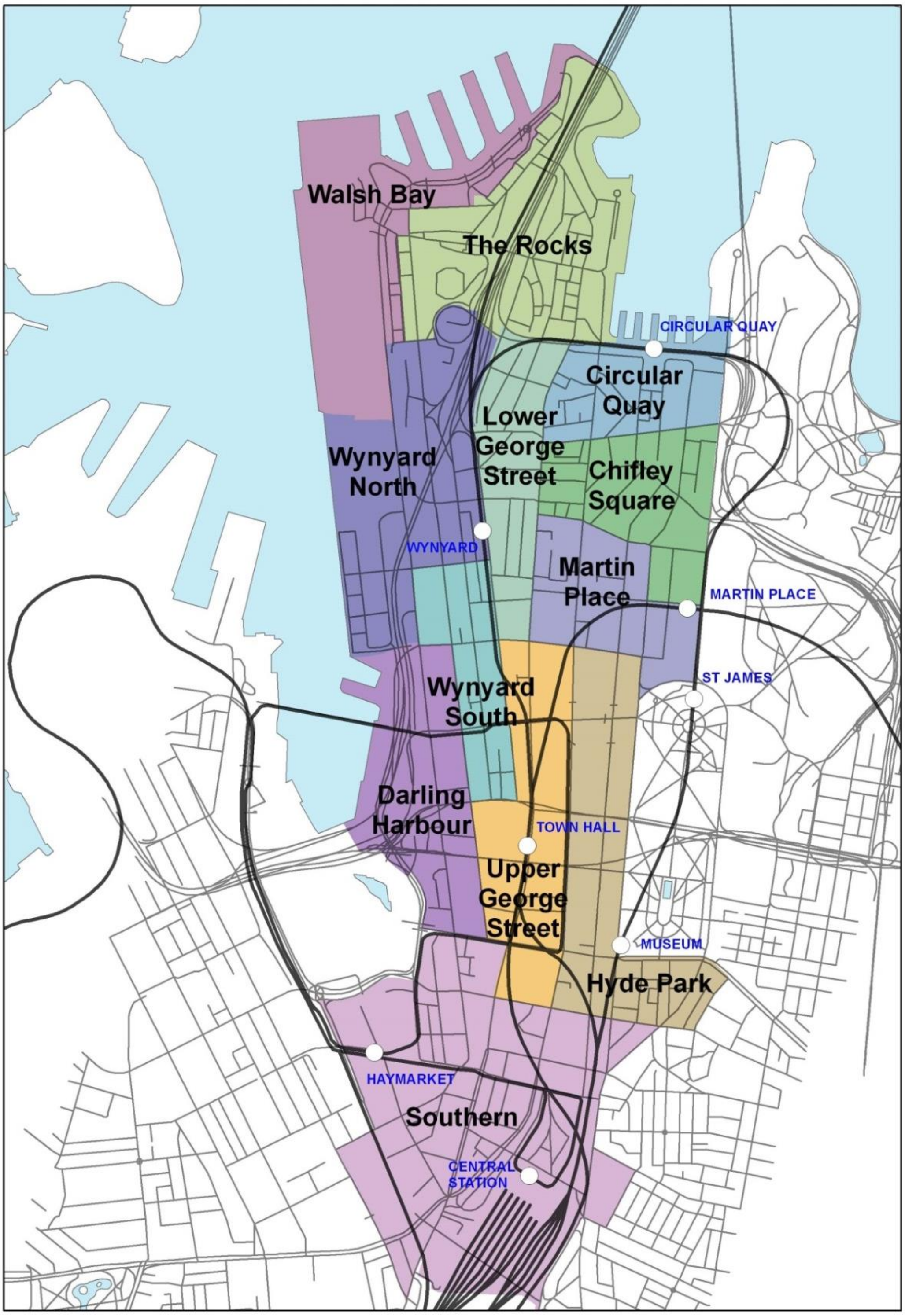

Figure 5.3. Finer spatial classification of Sydney office submarkets. Major rail transport infrastructure also displayed (stations in all-caps).

5.1.4 Fixed Time Effects

A series of half-yearly binary variables complete the lease database. Although face rental rates in Sydney are relatively steady, there was a spike in price just before the Global Financial Crisis in 2008, followed by a decline soon after (see Figure 5.4). These fixed time effects need to be accounted for in the model because lease contracts between January 2007 and September 2011 are combined in the database. For each lease contract, a binary variable representing the lease commencement date is used to measure fixed time effects; the variable takes the value of one if the lease commences in the specified half-year, zero otherwise. The basis for using the commencement date is that rental rates, particularly semi-gross rents that include base-year operating expenses, are negotiated based on the date of commencement. A 6-monthly scale was chosen because it is used for property market indicator reporting by the Property Council of Australia in a semi-annual "Office Market Report" (Property Council of Australia, 2011).

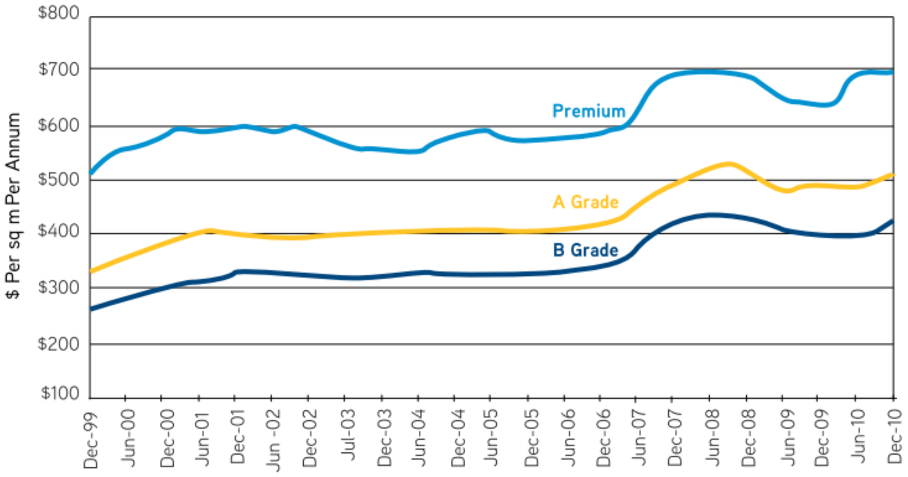

Figure 5.4. Sydney CBD average net face rents 1999-2011. Source: Colliers International Research (2011)

5.2 Descriptive Statistics

Two facets of the entire lease database are described in this section. First, statistics of the entire database are discussed. The second section looks at the subsample of the database containing lease contracts that disclose signing incentives. Appendix 2 includes additional descriptions of lease database subsamples.

5.2.1 Entire Lease Database

Table 5.2 presents descriptive statistics for all continuous variables in the lease database. To enable the description of rental rates for the entire dataset, it is necessary to have a common unit for face rent. Face rents on a net lease are not directly comparable with face rents on a semi-gross lease because the latter includes base year operating expenses in the face rent. However, because estimates of base year operating expenses are observed for all net lease contracts, it is possible to use Equation 5.1 to convert all net face rents into semi-gross face rents. Whenever rent from the entire dataset is used, as is the case in Table 5.2, all net face rents are converted to an equivalent semi-gross face rent by adding the estimate of first-year common area operating expenses to the face rent.

Table 5.2. Descriptive statistics of continuous variables for the entire dataset (N=673).

	Mean	Std. Dev.	Median	Minimum	Maximum
Tenancy Area (m^2)	899	1,804	345	29	24,141
Building Size (m^2 NLA)	27,495	18,514	21,203	2,917	85,551
Base Building Energy Intensity (MJ/m^2/yr.)	687	219	677	274	1,712
Semi-Gross Face Rent (A$/$m^2$/year)	687	193	650	320	1,446
Lease Term (months)	58.5	25.6	60	12	144
Floor of Tenancy	15.1	11.7	12	0	65
Number of Floors Leased	1.35	1.49	1	1	27
Bank Guarantee (months)	5.38	4.04	6	0	35
NABERS Energy Rating at Time of Lease	2.73	1.21	3.0	0	5.0
Walking Distance to Train Station (m)	216	108	232	3	443
Building Age at Commencement (years)	31.8	16.4	33	3	129

After converting all net rent observations into semi-gross rents, a wide range of rental rates (that include base year operating expenses) is evident in Table 5.2, from a minimum of A\$320/m^2/year to a maximum of A\$1442/m^2/year. According to the NABERS Energy certificate issued prior to each lease transaction, the mean star rating is 2.73 and median 3.0. Base building energy use intensity exhibits a similar range as semi-gross rent, varying by more than a factor of 5, from a minimum of 274 MJ/m^2/year to a maximum of 1,712 MJ/m^2/year. The question in this study is whether any of the variation in rental rates is due to this variation in energy efficiency characteristics of the asset.

All assets in the lease database are above the 2,000 m^2 size threshold for mandatory disclosure, although all lease transactions in the database occurred prior to full enforcement of the BEED Act. The size of buildings is also reflected in the micro-location of tenancies; which vary from the ground floor (zero) to the 65th floor. Most tenants only lease a single or partial floor. Lease terms averaged just less than 5 years, which was the modal lease term. With the compactness of the study area and concentration of urban transit, all the office buildings in the study can be considered accessible by public transit; the nearest train station is less than 450m walking distance away from every one of the assets, much less than the 1,000m threshold considered as "accessible" for Green Star credits (Green Building Council of Australia, 2008). As was briefly discussed in Section 3.2 during the description of the energy dataset, many central Sydney office assets were built around a boom period in the mid- to late-20th century, which creates a tight distribution of asset ages between 20 and 40 years old despite the range in Table 5.2 between 3 and 129 years old.

Table 5.3 presents these continuous variables categorised by the independent variable of interest: NABERS Energy ratings. Four NABERS Energy rating categories are explored: poor (1.5 and lower), below average (2 or 2.5), above average (3 or 3.5) and best practice (4 and above). To explain the logic behind these categories, a rating of 2.5 is meant to represent the NABERS benchmark for "average", but in this dataset the median is 3 stars. Four stars and above is used to define the high-performing energy efficient buildings because of their use as an aspirational target for local and state government agency procurement. The division at 1.5 stars is based on the author's experience that owners of assets at or below this threshold tend to avoid advertising their rating on external billboards (i.e. all advertisements for space that must comply with mandatory disclosure under the BEED Act are exclusively online). This indicates a perception that there is value in concealing NABERS Energy ratings of 1.5 stars (or lower).

The notable difference between groups is building energy use intensity, which is to be expected because it is highly correlated with the NABERS Energy rating. Sydney shows no bias towards large buildings being more energy efficient. Semi-Gross face rents in buildings with best practice NABERS Energy ratings appear to be lower than those in lower rated buildings.

Table 5.3. Descriptive statistics of continuous variables by NABERS Energy rating at the time of lease. Statistics are mean (standard deviation). See Table 5.2 for units.

NABERS Energy Rating Category	**Poor (0, 1, 1.5)**	**Below Avg. (2, 2.5)**	**Above Avg. (3, 3.5)**	**Best Practice (4, 4.5, 5)**	**All**
Tenancy Area	1000 (1,645)	701 (1,418)	887 (1,545)	1046 (2,507)	**899 (1,804)**
Building Size	29,791 (20,816)	27,252 (17,119)	27,644 (20,029)	25,717 (15312)	**27,495 (18,514)**
Energy Intensity	1032 (204)	733 (52.4)	627 (95.3)	458 (70.3)	**687 (219)**
Semi-Gross Face Rent	702 (229)	728 (191)	673 (196)	652 (144)	**687 (193)**
Lease Term	62.8 (28.3)	60.8 (26.6)	56.9 (23.3)	55.3 (25.4)	**58.5 (25.6)**
Floor of Tenancy	13.3 (10.5)	18.0 (12.5)	14.9 (12.1)	14.0 (10.7)	**15.1 (11.7)**
Bank Guarantee	5.43 (3.14)	6.51 (4.99)	5.22 (4.11)	4.41 (3.07)	**5.38 (4.04)**
Distance to Train	198 (106)	215 (103)	201 (108)	252 (106)	**216 (108)**
Building Age	30.1 (13.1)	33.1 (14.2)	30.7 (13.4)	33.5 (23.3)	**31.8 (16.4)**
N	122	162	234	155	**673**

Table 5.4 describes key binary variables captured in the lease database. The percentage of leases observed with a particular characteristic within unique groupings of binary variables is displayed. There is some minor spatial correlation between poor NABERS Energy ratings and the

prestigious City Core PCA submarket. The finer definition of Sydney submarkets distributes this block of energy inefficient assets amongst three separate smaller submarkets. The NABERS Energy performance distribution of asset quality is balanced for A- and B-Grade assets, with Premium-grade assets likely to have poor performance. The observation in Table 5.3 that semi-gross face rents are high in poor NABERS Energy assets could be a result of location in prime submarkets and the provision of Premium-grade services. Hence the multivariate model developed in Section 5.3 is necessary to isolate the effect of asset energy performance characteristics on rental rates.

Table 5.4. Frequencies of categorical variables by NABERS Energy rating groups. Percentage is the relative incidence of each star rating group within each group of independent binary variables. Integer is the number of assets (Percentage x N).

	Poor (0, 1, 1.5)	**Below Avg. (2, 2.5)**	**Above Avg. (3, 3.5)**	**Best Practice (4, 4.5, 5)**	**All**
PCA Submarket					
City Core	80.3% (98)	81.5% (132)	45.3% (106)	27.1% (42)	**56.1% (378)**
Midtown	17.2% (21)	12.3% (20)	23.5% (55)	14.8% (23)	**17.7% (119)**
Western Corridor	2.5% (3)	6.2% (10)	30.8% (72)	53.5% (83)	**25% (168)**
Southern	- (0)	- (0)	0.4% (1)	4.5% (7)	**1.2% (8)**
Smaller Submarket					
Circular Quay	18.9% (23)	14.8% (24)	5.6% (13)	1.9% (3)	**9.4% (63)**
Chifley Square	36.9% (45)	47.5% (77)	19.7% (46)	13.5% (21)	**28.1% (189)**
Martin Place	18.9% (23)	9.9% (16)	15% (35)	5.8% (9)	**12.3% (83)**
Lower George St.	5.7% (7)	9.3% (15)	5.1% (12)	5.8% (9)	**6.4% (43)**
North Wynyard	- (0)	4.9% (8)	20% (47)	13.5% (21)	**11.3% (76)**
South Wynyard	2.5% (3)	0.6% (1)	7.3% (17)	32.2% (50)	**10.5% (71)**
Darling Harbour	- (0)	0.6% (1)	3.4% (8)	7.7% (12)	**3.1% (21)**
Upper George St.	6.6% (8)	1.2% (2)	17.9% (42)	3.2% (5)	**8.5% (57)**
Hyde Park	10.7% (13)	11.1% (18)	5.6% (13)	11.6% (18)	**9.2% (62)**
Southern	- (0)	- (0)	0.4% (1)	4.5% (7)	**1.2% (8)**
Quality Grade					
Premium	26.2% (32)	12.3% (20)	7.7% (18)	5.2% (8)	**11.6% (78)**
A-Grade	30.4% (37)	50% (81)	45.3% (106)	50.3% (78)	**44.9% (302)**
B-Grade	35.2% (43)	35.8% (58)	37.6% (88)	44.5% (69)	**38.3% (258)**
C-Grade	8.2% (10)	1.9% (3)	9.4% (22)	- (0)	**5.2% (35)**
Operating Expenses					
Net	42.6% (52)	38.3% (62)	37.2% (87)	63.9% (99)	**44.6% (300)**
Semi-Gross	57.4% (70)	61.7% (100)	62.8% (147)	36.1% (56)	**55.4% (373)**
N	**122**	**162**	**234**	**155**	**673**

5.2.2 Leases with disclosed incentives

Subsamples of the lease database will be of interest in assessing the robustness of findings in the model constructed with the entire sample. Of most interest are 340 lease contracts that disclose signing incentives. This subsample is explored in greater detail in Tables 5.5 and 5.6. Descriptive statistics are provided for a further four subsamples in Appendix 2: net leases, semi-gross leases, prime assets and secondary assets.

Table 5.5. Descriptive statistics of continuous variables for all lease contracts with known signing incentives (N=340).

	Mean	**Std. Dev.**	**Median**	**Minimum**	**Maximum**
Tenancy Area (m^2)	663	1,292	270	37	12,687
Building Size (m^2 NLA)	27,244	17,399	24,970	2,917	73,500
Base Building Energy Intensity (MJ/m^2/year)	660	209	671	274	1,712
Semi-Gross Face Rent (A\$/m^2/year)	671	179	640	320	1,430
Effective Semi-Gross Rent – 0% (A\$/m^2/year)	614	197	559	287	1,550
Effective Semi-Gross Rent – 4% (A\$/m^2/year)	603	193	552	285	1,495
Effective Semi-Gross Rent – 10% (A\$/m^2/year)	588	189	537	283	1,419
Lease Term (months)	56.2	24.1	60	12	144
Floor of Tenancy	16.9	12.9	14	0	65
Number of Floors Leased	1.22	0.95	1	1	10
Bank Guarantee (months)	5.74	4.06	6	0	24
NABERS Energy Rating at Time of Lease	2.82	1.17	3	0	5
Walking Distance to Train Station (m)	228	102	233	15	443
Building Age at Commencement (years)	32.2	12.3	34	7	85

For the 340 observations that include signing incentives, a measure of “effective rent” that represents the net financial liability from the tenant viewpoint is calculated. In this study, effective rent is defined as an annual level payment representing the net present value of all monthly cash flows specified in the lease contract, including fixed percentage nominal rent escalation clauses and signing incentives. Note that this definition of effective rent differs from that used by Eichholtz et al. (2010, 2013) in the green building premium literature. Eichholtz is interested in the owner viewpoint and defines effective rent as the net outcome of rental income and vacancy costs, calculated as occupancy rate multiplied by rental income.

In this study, effective rent for each of the 340 observations is calculated as specified in Brueggeman and Fisher (2011; 273-277), except the common measurement of face rent is semi-gross instead of net because it is not possible to obtain net face rents for the sample of semi-gross lease contracts. One subjective input to the calculation of effective rent is the discount rate. Effective rents using three different discount rates – zero, 4% and 10% – were calculated and are shown in Table 5.5. These discount rates were chosen because a zero discount rate is implicit in the calculation of many incentive sums (see Equation 5.2), the modal fixed percentage rent escalation within the lease database is 4%, and Brueggeman and Fisher suggest using 10%.

Table 5.6. Frequencies of binary variables for all lease contracts with known signing incentives (N=340). Percentage is the relative incidence of each star rating group within each group of independent binary variables. Integer is the number of assets (Percentage x N)..

PCA Submarket	
City Core	58.2% (198)
Midtown	10.3% (35)
Western Corridor	30.6% (104)
Southern	0.9% (3)
Quality Grade	
Premium	5.6% (19)
A-Grade	40.9% (139)
B-Grade	46.8% (159)
C-Grade	6.8% (23)
Operating Expenses	
Net	44.7% (152)
Semi-Gross	55.3% (188)

Smaller Submarket	
Circular Quay	8.8% (30)
Chifley Square	31.5% (107)
Martin Place	11.2% (38)
Lower George Street	6.8% (23)
North Wynyard	10.0% (34)
South Wynyard	15.6% (53)
Darling Harbour	5.0% (17)
Upper George Street	3.5% (12)
Hyde Park	6.8% (23)
Southern	0.9% (3)

Another subjective decision was the treatment of mid-term market rent reviews observed in approximately 30 rental contracts. In most cases, these mid-term market rent reviews only took effect if a market rent review would raise the rent beyond the increase calculated with a fixed percentage rent review (a “super-hard” ratchet). Given the expense of market rent reviews and the relative steadiness of Sydney market rents (Figure 5.4), it was assumed that the fixed percentage rent review would be implemented. For the few leases with mid-term market reviews and no super-hard ratchet, rent following a market rent review was assumed to be equal to the rent in the period prior to the market rent review (i.e. a typical hard ratchet). Recall that leases with mid-term market reviews within the first 12 months of the term were discarded as being unrepresentative of open-market face rents.

5.3 Modelling Semi-Gross Face Rent

As with previous investigations of environmental premiums in commercial office property (Eichholtz *et al.*, 2010, Fuerst and McAllister, 2011b, Wiley *et al.*, 2010), a semi-log ordinary least squares hedonic pricing model is applied to the lease database described above. The hedonic price model consists of multivariate regression techniques that seek to identify the marginal price effects of individual product characteristics expected to provide the owner with economic utility (Rosen, 1974). While developed to measure the equilibrium between supply and demand of consumer products, hedonic price models became useful tools for property market analysis; Clapp (1993) discusses how this method has become conventional within commercial office market analyses.

This hedonic pricing model seeks to explain the price of rent in central Sydney, specifically the contribution of asset energy consumption to rent. The standard multivariate regression form used for a hedonic price model is:

$$\text{Rent} = \alpha + \sum_{i=1}^{n} \beta_i X_i + \gamma G + \varepsilon \tag{5.3}$$

where G is the unique characteristic of interest (energy consumption in this study), γ measures the contribution of G to the price of rent, $\sum_{i=1}^{n} \beta_i X_i$ represents a vector of n control characteristics X_i with β_i effect on rent, ε represents stochastic error, and α represents the baseline constant if all X_i and G equal zero. The hypothesis in this study (H_1) is that γ is not equal to zero[5], creating a null hypothesis (H_0) that γ equals zero:

$$\begin{aligned} \mathrm{H}_0&:\ \gamma = 0 \\ \mathrm{H}_1&:\ \gamma \neq 0 \end{aligned} \tag{5.4}$$

For the semi-log specification in this study, the dependent variable ("Rent" in Equation 5.3) is expressed as the natural logarithm of semi-gross face rent per square metre. The regression tests whether face rental price for each lease contract observation, *j*, can be explained as a function of independent characteristics extracted from each contract and other relevant data (vector variables in bold):

$$\ln(RENT_j) = \alpha + \boldsymbol{\beta_1 MKT_j} + \boldsymbol{\beta_2 AST_j} + \boldsymbol{\beta_3 LEASE_j} + \boldsymbol{\beta_4 LOC_j} + \boldsymbol{\gamma ENERGY_j} + \varepsilon_j \tag{5.5}$$

$\boldsymbol{MKT}$ represents fixed market effects associated with the half-year the contract was signed. It is a vector of binary variables from January 2007 through September 2011 (the last "half-year" only contains observations between July and September 2011). $\boldsymbol{AST}$ is a vector of asset characteristics. Asset age, quality rating and proximity to rail transit are included in this vector. $\boldsymbol{LEASE}$ is a vector of lease contract characteristics. Tenancy floor level, tenancy area, operating

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[5] During the discussion on how to represent *G* in the model, this hypothesis is refined as follows: H_1: $\gamma<0$ when a metric representing raw energy consumption is used to represent *G;* H_1: $\gamma>0$ when NABERS Energy ratings are used to represent *G*. The reason is the negative association between NABERS Energy ratings and energy consumption (i.e. low energy consumption begets a high NABERS Energy rating).

expense liability, and lease term length are included. $\boldsymbol{LOC}$ accounts for spatial effects associated with the location of the asset. Binary variables representing submarkets constitute the variables in this vector. $\boldsymbol{ENERGY}$ is G, the independent variable of interest from Equation 5.3, representing a variety asset energy consumption metrics – unique NABERS Energy ratings, groupings of NABERS Energy ratings, and raw energy use intensity – in alternate specifications. Finally, ε_j, the stochastic error, and α, the baseline constant, are unchanged from Equation 5.3.

The model developed in this section uses the entire lease dataset. Signing incentives are only observed in half the dataset, so it must be assumed – in this model only – that incentives are a fixed market effect controlled by $\boldsymbol{MKT}$ in this regression. However, the descriptive statistics noted that this assumption is debatable, so Section 5.4 will describe two regression specifications that allow effective rent to be the dependent variable, even though it is only observed in slightly more than half of all observations.

Starting with the dependent variable, the following sections describe the specification of Equation 5.5 in more detail. Five representations of $\boldsymbol{ENERGY}$ are developed along with two specifications of $\boldsymbol{LOC}$ to account for the alternative submarket boundaries explored during data collection. To examine every permutation of these representations, ten model specifications, summarised below, are tested:

Specification 1A: $\boldsymbol{ENERGY}$ omitted, $\boldsymbol{LOC}$ = PCA submarkets
Specification 2A: $\boldsymbol{ENERGY}$ = NABERS Energy groupings, $\boldsymbol{LOC}$ = PCA submarkets
Specification 3A:$\boldsymbol{ENERGY}$ = Unique NABERS Energy ratings, $\boldsymbol{LOC}$ = PCA submarkets
Specification 4A:$\boldsymbol{ENERGY}$ = Nat. log. of asset energy use, $\boldsymbol{LOC}$ = PCA submarkets
Specification 5A:$\boldsymbol{ENERGY}$ = Quintiles of asset energy use, $\boldsymbol{LOC}$ = PCA submarkets
Specification 1B: $\boldsymbol{ENERGY}$ omitted, $\boldsymbol{LOC}$ = Smaller submarkets
Specification 2B:$\boldsymbol{ENERGY}$ = NABERS Energy groupings, $\boldsymbol{LOC}$ = Smaller submarkets
Specification 3B:$\boldsymbol{ENERGY}$= Unique NABERS Energy ratings, $\boldsymbol{LOC}$ = Smaller submarkets
Specification 4B:$\boldsymbol{ENERGY}$ = Nat. log. of asset energy use, $\boldsymbol{LOC}$ = Smaller submarkets
Specification 5B: $\boldsymbol{ENERGY}$ = Quintiles of asset energy use, $\boldsymbol{LOC}$ = Smaller submarkets

5.3.1 Rent

The natural logarithm of semi-gross face rent at commencement is used as the dependent variable, $\ln(RENT)$. As was explained in Section 5.2.1, semi-gross face rent is the only comparable measure of rent that can be calculated for the entire lease database. Net rental contracts disclose estimates of the base year operating expenses that can be added to the net face rent using the relationship described in Equation 5.2 to calculate an equivalent semi-gross face rent. To produce a comparable database of net face rents, the base year operating expenses from all semi-gross contracts would need to be known, but this figure is not calculated until the end of the first year on the contract so it is not disclosed within the text of a lease contract. Appendix 3 runs an identical model on the subsample of net lease contracts using net face rent as the dependent variable.

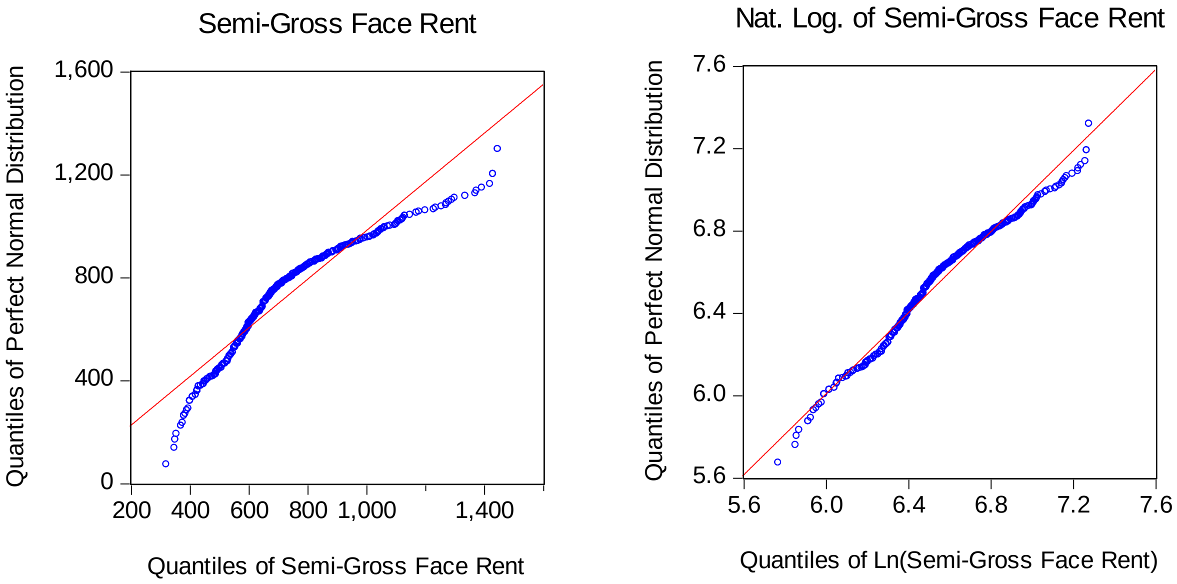

Figure 5.5. Quantile-quantile plots of all rent observations (left) and the log-transformation of all rent observations (right)

An examination of the raw, untransformed, rent data (Figure 5.5, left side) suggests a non-linear distribution that deviates away from perfect normality. The transformation using the natural logarithm reveals a much better fit within a standard normal distribution. Hence this study, along with all prior studies of the influence of energy performance on office rental rates, uses a semi-log specification, in which the dependent variable is the natural log transformation of rent, while most (but not all) of the independent variables are left untransformed. The interpretation of the effect of each independent variable coefficient is the percentage effect on rent of a one-unit increase in the independent variable, with a slight correction for binary independent variables (Halvorsen and Palmquist, 1980). Two of the independent variables are specified as log-transformations (energy consumption in specification four and tenancy area), so the interpretation of the effect of these transformed variables is an elasticity; the percentage change in semi-gross face rent as a result of a 1% change in the independent variable.

5.3.2 Asset Energy Consumption

As the independent variable of interest, five alternatives are specified to represent $\boldsymbol{ENERGY}$. For control purposes, specification 1 omits $\boldsymbol{ENERGY}$. Specification 2 groups NABERS Energy ratings using a binary variable for the “poor”, “below average”, “above average” and “best practice” groupings explored in Tables 5.3 and 5.4. Specification 3 uses binary variables for each unique NABERS Energy rating up until 4 stars (i.e. a variable for star ratings of 0, 1, 1.5, 2, 2.5, 3, 3.5, 4, and 4.5-plus). Only two lease contracts are for space in a 5-star NABERS Energy rating, hence these are grouped with the 4.5-star cohort.

The final two specifications use measured energy consumption to represent $\boldsymbol{ENERGY}$. An examination of energy consumption data (Figure 5.6) reveals a long right tail, indicating a lognormal distribution. Hence, specification four uses the natural log of asset energy use intensity at the signing date of the lease to test the rent elasticity of the underlying performance characteristic of energy efficiency. To allow for additional functional flexibility, specification five creates binary variables for each quintile of asset energy use intensity. The first, or “highest”, energy consumption quintile contains leases in assets consuming in excess of 817 MJ/m^2/year at the time of lease. The second quintile identifies leases in assets consuming between 706 and 817 MJ/m^2/year, while the third quintile contains leases in assets consuming between 610 and 706 MJ/m^2/year. The fourth quintile features leases in assets consuming between 502 and 610 MJ/m^2/year, with the fifth, or “lowest”, quintile identifying leases in the most energy efficient assets consuming below 502 MJ/m^2/year.

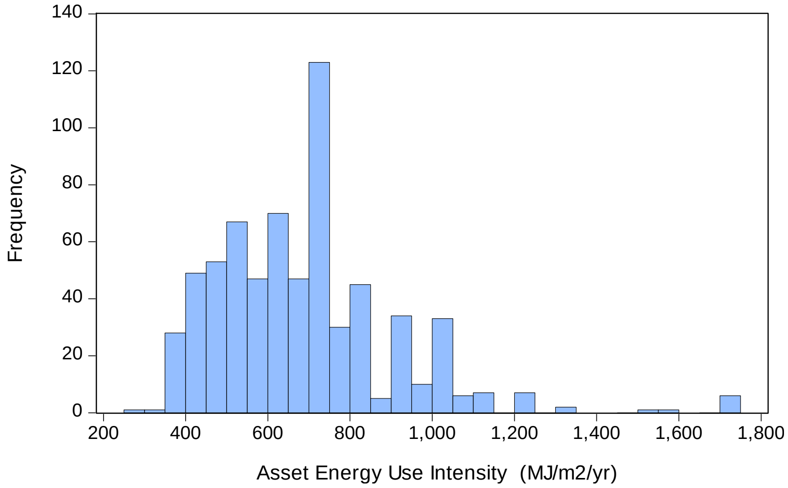

Figure 5.6. Distribution of asset energy use intensity at the time of lease.

The expectation for $\boldsymbol{ENERGY}$ is a positive association between NABERS Energy ratings and face rent as well as the analogous negative association between energy consumption and face rent. Chapter 1 reviewed the theoretical literature, which argued that energy consumption should be taken into account in rental rates using rational behaviour logic (lower operating costs, less regulatory compliance) and less quantifiable motivations such as corporate social responsibility. Nearly every econometric study at the asset level has demonstrated a positive relationship between rental income and the level of environmental or energy certification obtained by an asset owner. In particular, Newell *et al.* (2011) modelled the central Sydney market at the asset scale and found a positive relationship between NABERS Energy ratings and rental income to owners of many assets featured in the lease database. Although Chapter 1 also argued that valuation bias, occupancy effects, and market timing effects indicate econometric studies of rent at the asset scale do not necessarily indicate tenants are willing to pay for energy efficiency, there is very little literature arguing that tenants should be indifferent to energy efficiency (Warren-Myers, 2012). Hence the hypothesis expressed in Equation 5.4 can be refined further; γ in Equation 5.5 is likely to be positively associated with NABERS Energy ratings (which increase as energy efficiency increases) and negatively associated with measurements of energy consumption (which increase as energy efficiency decreases) if the theory that tenants are willing to pay for energy efficiency is valid.

5.3.3 Spatial Location

During data construction, two alternative designations of submarket boundaries were discussed: the well-known PCA submarkets and a finer delineation of submarkets proposed earlier in this chapter. Both groupings of submarket boundaries will be modelled in this study to test the conventional and experimental controls for location as binary variables representing the vector $\boldsymbol{LOC}$.

The PCA submarkets are the conventional designations for spatial differences when reporting on indicators of the Sydney commercial office property market (Colliers International Research, 2011). $\boldsymbol{LOC}$ in specification A uses binary variables representing these PCA submarkets to account for the effect of location on rental rates. The City Core submarket variable is omitted to serve as the reference location. As its name suggests, this PCA submarket is expected to be the most valuable and have the highest rents.

Section 5.1.3.3 argued that it may be possible to better represent the effects of location on rental rates using a finer separation of these submarkets. $\boldsymbol{LOC}$ in specification B uses the smaller submarkets as an experimental control for location. Circular Quay, one of the submarkets extracted out of the PCA City Core, is used as the reference location. This submarket is expected to have the highest rents within the prestigious City Core given its prime location adjacent to Sydney Harbour and the iconic Sydney Opera House.

5.3.4 Lease Contract Terms

In all model specifications, ***LEASE*** is represented by four variables: tenancy floor level, tenancy area, operating expense liability and lease term length. The correlation between tenancy floor level and rent (0.6949) is the highest in the lease database, so the effect of tenancy floor level on rent is expected to be very strong. Figure 5.1 demonstrated one asset with a clear linear relationship between tenancy heights and face rents. With evidence of a linear relationship, tenancy floor level is represented in ***LEASE*** with a flexible polynomial form that allows for the possibility of declining marginal returns; i.e. if the difference in face rent between tenancies on the 60th or 61st floor is less than the difference between the 10th or 11th floor. Therefore, one variable measures "average floor height" of each tenancy and a second variable is measures "average floor height squared". The signature of declining marginal returns to floor height in this construction would be a positive coefficient for "average floor height" and a smaller negative coefficient for "average floor height squared".

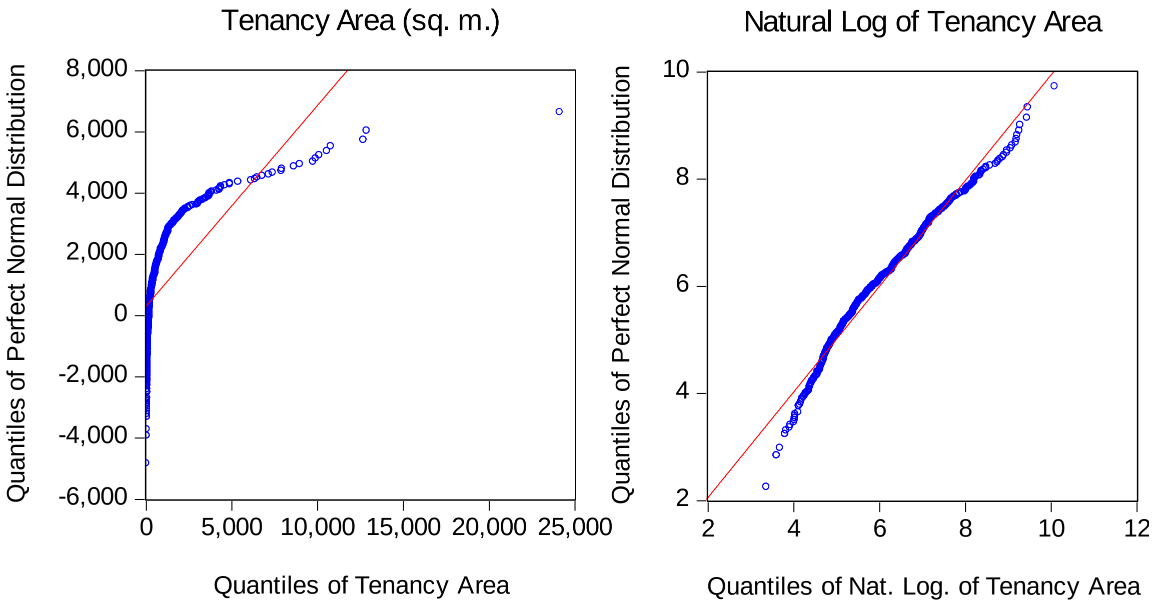

Figure 5.7. Quantile-Quantile plots of tenancy area and its natural log transformation

The next variable included in ***LEASE*** is tenancy area. With the independent variable being a transformation of rent per square metre, one expects that as tenancy area increases, owners may be inclined to offer lower rents per square metre to large tenants as a result of potentially lower vacancy and transaction costs. An investigation of the data on tenancy area (Figure 5.7) shows a similar log-normal distribution as the dependent variable. Hence the relationship between tenancy area and semi-gross face rent will be modelled as an elasticity, with a logarithmic transformation of tenancy area specified in ***LEASE***.

The dependent variable for all 673 lease observations is semi-gross face rent, either taken directly from a semi-gross lease or created by summing a net face rent with estimated base year operating expenses. However, two binary variables representing the underlying structure of base year operating expense payment liability – one for net and one for semi-gross – were created during the data extraction process to control for the structure of payments. The variable representing a semi-gross lease will act as the reference and be omitted from all model specifications, meaning the coefficient of the net lease variable in ***LEASE*** measures the effect on semi-gross face rent of choosing a net lease payment structure over a semi-gross lease payment structure. According to the theory expressed in equation 5.2, differences between operating expense payment structures should not matter in an open competitive market. All tenants, net and semi-gross, share the same risk in regard to operating expense increases, thus the coefficient of the net lease variable in ***LEASE*** is expected to be zero. However, the author has spoken with valuation professionals in the central Sydney office lease market who state that net and semi-gross leases are valued separately in market rent reviews (i.e. a net face rent plus base-year operating expenses is not used as a comparable in a semi-gross face rent review), so there is a possibility that lease structure may have an effect on face rent because of market segmentation.

The fourth category of variables making up ***LEASE*** is a set of binary variables representing the length of the lease term in the contract. Analogous to the discussion on tenancy area, owners are likely willing to offer face rent discounts for tenants that commit to long-term accommodation because of reduced vacancy and transaction costs. In addition, owners will also benefit via security against future market downturns with a long-term tenant. However, at the opposite extreme of lease term length, the analogy with tenancy area falls apart because the context of short-term leases is likely to lead to face rent discounts while fixed costs associated with small tenancies are likely to produce face rent premiums (relative to larger tenancies). Owners with vacant space in a distressed market are likely to offer a range of incentives to fill that vacant space, one of which may be face rent discounts for short-term contracts. This leads to a situation where the highest face rents as a function of lease term length are expected to be in the modal lease, where the owner is neither benefitting from a relatively long-term tenant nor behaving as if he is anxious to fill vacant space to mitigate the costs of ownership. A set of three binary variables is created to model this expectation. All observations with term lengths that round to the modal lease term length, five years, are designated as “average-term” length (i.e. between 4.5 and 5.5 years). Observations of contracts with less than 4.5 years in the term are designated “short-term” leases while contracts with greater than 5.5 years are designated “long-term” leases. Figure 5.8 illustrates the distribution of lease term lengths in the database, along with the divisions of short, average and long term lengths. The variable for “average-term” length is omitted from ***LEASE***. This means the coefficients for “short-term” and “long-term” leases measure the effects of lease term length on rent relative to an identical lease signed for an “average-term”. Given the discussion above, both coefficients are expected to be negative.

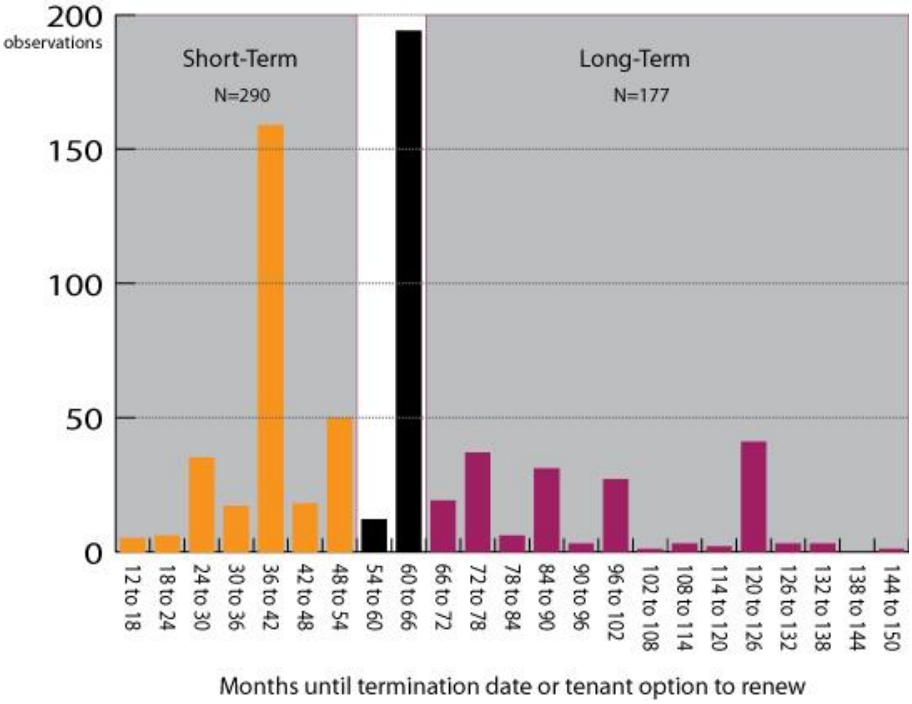

Figure 5.8. Histogram of lease term length for the entire lease dataset. Average term length in black (N=206).

Two metrics of lease contract terms captured for the lease database are not included in ***LEASE***. The number of floors leased by a particular tenant is excluded because this variable is highly non-linear (most observations take a value of 1). However, the number of floors is correlated with tenancy area, so effects of tenancy size on face rent are likely to be accounted for in the continuous variable for tenancy area.

Also not included in ***LEASE*** is a representation of the bank guarantee amount required of a tenant. The reason for this exclusion is the presence of measurement error as a result of differences between asset owners in assessing the credit quality of tenants and willingness to accept default risk. For example, a six month bank guarantee in one property may represent a different perception of risk as a six month bank guarantee in another asset. Other variables in the dataset, in particular the asset quality rating and fixed market effects, may be adequately correlated with bank guarantee requirements to enable their effect to be included in this model. However, Benjamin *et al.* (1992) reported that security deposits did not appear to be a fixed market effect in four office assets in North Carolina, so future models may be able to improve on the explanatory power of this study.

In an effort to include data on bank guarantee sums, this study attempted to account for measurement differences by creating a set of four binary variables to proxy relative perceptions of tenant default risk. Three binary variables indicated whether the number of months of rent required for the bank guarantee was “below average”, “average” or “above average” for each unique asset. The fourth binary variable, “institutional tenant”, was created for all high-quality tenants not required to deposit a bank guarantee. However, there were insufficient observations in a number of assets to allow an assessment of “average” for the particular asset, meaning that this approach was just as likely to introduce bias as control for bias. The “institutional tenant” variable is used later in this study (Section 5.4) to estimate the probability that signing incentives are disclosed in a lease contract.

5.3.5 Asset Characteristics

The vector variable ***AST*** includes fixed asset characteristics that are expected to have an influence on semi-gross face rent, including: asset age, quality of services and proximity to rail transit stations. Asset age is included to estimate the effect of asset vintage on face rent. Such information could potentially be introduced via an asset quality rating, but in reviewing the specifications of quality rating assessment (Property Council of Australia, 2006b) there is no criterion representing asset vintage. The European literature examining the effect of asset energy disclosures on rent at the lease scale use asset vintage to proxy service quality, but produce highly inconsistent results with that variable (Kok and Jennen, 2012, Fuerst *et al.*, 2013) suggesting there is value in including both service quality and vintage indicators.

The expected effect of vintage on rent is non-linear; younger assets consistently command the highest rents in a meta-analysis of hedonic house price models (Sirmans *et al.*, 2005), but long-lived assets can possess cultural heritage value and command higher rents by virtue of limited supply. A distribution of asset age within the lease database in this study is shown in Figure 5.9. A long right tail is visible, with 15 observations in four assets constructed at least 75 years before lease agreement. Most leases are in assets built in the 1950s or later. The other notable feature is a gap in the distribution showing a relative lack of leases in assets between 25 and 30 years old, indicating two clear construction cycles in the central Sydney market. The reason for this gap is a long pause in new supply just before a construction boom that flooded the market in the early 1990s (Hendershott, 2000).

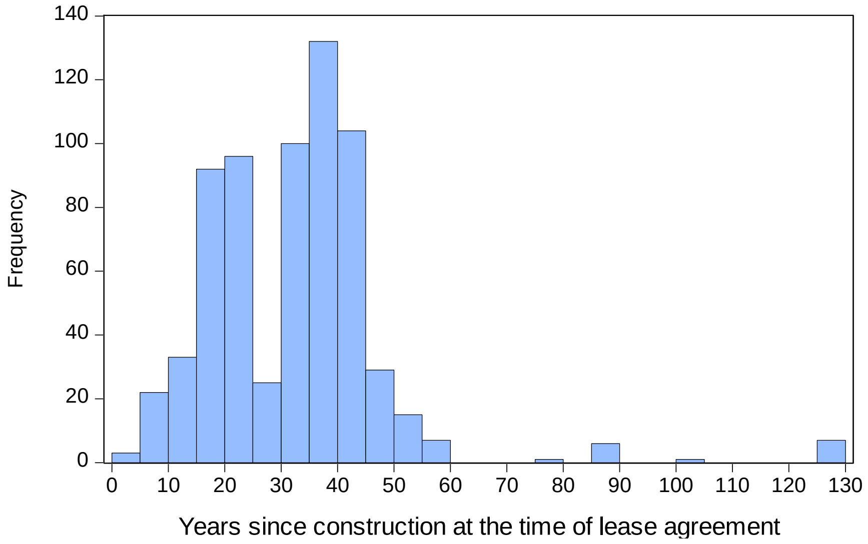

Figure 5.9. Distribution of asset age among all lease observations (N=673).

From this distribution, the effect of vintage on rents is best represented in ***AST*** as a series of three binary variables indicative of each construction cycle. The first of these, “heritage asset”, equals one for all assets in the long right-hand tail built more than 60 years prior to lease transaction. The construction cycle between the Second World War and the late 1970s, represented in Figure 5.9 through a large number of leases in assets between 30 and 60 years old, is captured in a “post-war asset” binary variable. Finally, the most recent construction cycle, from 1990 through the present, is captured with a binary variable representing a “new asset”. The “post-war asset” variable is omitted from ***AST*** as the reference category. This means that the coefficient of “heritage asset” is expected to be positive due to rent premiums for a limited supply of culturally significant assets relative to the plentiful post-war asset supply. “New asset” is also expected to have a positive coefficient representing higher rents in new assets, though this is the value most likely related to the quality of services offered, so rent differences between “new” and “post-war” assets may be reflected in both vintage and asset service quality.

Asset service quality is the second variable included in ***AST***. No adjustment to the raw data captured for the lease database on asset service quality (Section 5.1.3.2) is necessary. Binary variables representing each service quality grade are included in the model, with the “A-grade” variable excluded as the reference category. As a result, leases in “Premium-grade” assets are expected to have a rent premium above A-grade assets, while “B-grade” and “C-grade” assets will lead to rent discounts relative to A-grade assets. The coefficient for “C-grade” assets is expected to be more negative than the coefficient for “B-grade”.

The third variable included in ***AST*** is walking distance to rail transit. Kok and Jennen (2012) found this indicator to be negatively associated with face rent in Dutch office buildings. This study uses the same construction as Kok and Jennen, specifying the untransformed distance to rail transit, in metres, as an independent variable in $\boldsymbol{AST}$.

The one asset characteristic captured in the lease database but not specified in this model is total square metres of office NLA within each unique asset. Between the variable for tenancy area (included in $\boldsymbol{LEASE}$) and the service quality grade variables described above, the relationship between asset size and face rent is already included in the model. For example, to be a Premium-Grade asset in central Sydney, an asset must be greater than 30,000 m^2 of total NLA to proxy the view amenity (Property Council of Australia, 2006b).

5.3.6 Fixed Market Effects

The ten binary variables described in Section 5.1.4 represent fixed market trends in $\boldsymbol{MKT}$. A proxy of the market conditions at lease commencement is represented by the half-year – January to June or July to December – of the commencement date. As a reference variable, January to June 2007 is omitted. Embedded in each of these variables are a range of market indicators that influence the Sydney leasing market over time: white-collar employment, supply expectations, vacancy, interest rates, macroeconomic conditions, capital markets, and so on. Figure 5.4 (in Section 5.1.4) presents a general expectation of face rents as a function of time[6]. Relative to the reference in this model (January to June 2007), face rents are expected to rise toward the end of 2007 and in early 2008, and then level out until the Global Financial Crisis depresses the market in late 2009. A market-segmented recovery begins in early 2010; recovery is rapid for the Premium-grade sector and slower for lower quality assets.

For the model described in this section of the complete lease dataset, the time variables representing fixed market effects also capture lease signing incentives through an assumption that incentives are also a function of market conditions. In the next section, 5.4, a two-stage model is introduced that relaxes this assumption.

5.3.7 Estimation Method and Standard Error Adjustments

Hedonic price models are typically estimated with ordinary least squares multivariate regression techniques (Sirmans *et al.*, 2005). In this study, EViews software is used to estimate the coefficients of Equation 5.5 using ordinary least squares. To meet the assumptions behind ordinary least squares regression, two adjustments to the standard errors in each model output are necessary based on *ex ante* tests of the lease dataset.

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[6] Note that Figure 5.4 is of net face rents, not the semi-gross face rent metric used in this study. Some difference between the model output and trend in Figure 5.4 is expected because of the influence of operating costs on semi-gross face rent.

First is a finite population correction, which reduces standard errors because the number of observations is more than a trivial sample of the entire stock of office space in central Sydney. Colliers International Research (2011) estimates the four PCA submarkets in central Sydney contained 4.8 million m^2 of office space in the first half of 2011. The 673 observations in the lease database cover 0.6 million m^2, so approximately 12.6% of the market is observed in a lease transaction. Cochran (1977) suggests multiplying the standard errors by a correction factor of $\sqrt{(1 - fraction\ observed)}$ when the sample exceeds 10% of the population. Thus, all standard errors in the regression output are multiplied by $\sqrt{(1 - 0.126)}$, or 0.935.

Second, Lagrange Multiplier tests on the residuals in each model output indicate the presence of minor heteroscedasticity, likely caused by the presence of multiple leases in individual assets. To correct for this, White's heteroscedasticity-consistent standard errors (often called "robust standard errors" in the literature) are used to determine significance thresholds. Typically, this correction has the effect of marginally increasing the standard errors. In combination, the finite population correction and heteroscedasticity correction work in opposite directions, so the net influence of these corrections is expected to be minimal.

5.4 Modelling Effective Semi-Gross Rent

The model of face rent described above requires an assumption that signing incentives are a function of market conditions at the time of lease. However, this may not be accurate if Sydney tenants negotiate incentives along with face rent during a lease agreement, thus creating a shadow price, the "effective rent". Anecdotal knowledge of the Sydney office market acquired during this study and the increase in variance associated with effective rent for the subsample of lease observations with disclosed incentives (Section 5.2.2) suggest that signing incentives are not uniformly based on market conditions. This section relaxes the assumption that signing incentives are a function of market conditions.

A model using nearly the same specification as described in Section 5.3 is run for the subsample of lease contracts where signing incentives are observed. Effective rent becomes the dependent variable. A concern with this approach is sample selection bias in the event that disclosure of incentives is non-random. A test for sampling bias effects is presented using a selection model that estimates the probability of observing signing incentives. The concern is correlation between the stochastic errors from the truncated model of all 340 observations with observed incentives and the stochastic errors from the selection model. Such a correlation would indicate that an unobserved characteristic influences both effective rental rates and the probability of observing effective rent.

In the event of significant correlation, a two-stage model based on the Heckman correction (Heckman, 1979) is developed. This model assumes the subsample of lease contracts with observed signing incentives is not random and estimates the probability of observing each of the 340 leases with effective rent. This probability is included as a regressor in an adjusted model of effective rent that takes sampling bias into account.

5.4.1 Subsample Ordinary Least Squares Regression

To include signing incentives in the model specified by Equation 5.5, the dependent variable is changed from a measure of face rent at commencement to effective rent over the entire lease term ($EFFRENT$). Only 340 lease contracts disclose signing incentives, so the inclusion of effective rent as the dependent variable requires the loss of 333 observations. The structure of exogenous independent variables on the right hand side of the model remains the same:

$$\ln\left(EFFRENT_j\right) = \alpha + \boldsymbol{\beta_1 MKT_j} + \boldsymbol{\beta_2 AST_j} + \boldsymbol{\beta_3 LEASE_j} + \boldsymbol{\beta_4 LOC_j} + \boldsymbol{\gamma ENERGY_j} + \varepsilon_j \quad (5.6)$$

Section 5.2.2 describes the process of calculating effective rent, which represents an annual level payment representing the net present value of all monthly cash flows specified in the lease contract (face rent, nominal rent escalation over time, and signing incentives). The only measure of effective rent that is comparable across all lease contracts is semi-gross rent, which includes the base year of common area operating costs in the rent price[7]. For every lease contract, three values of effective rent were calculated by varying the rate used to discount future cash flows. The choice of discount rate did not affect any modelling results, so this study only features effective rent calculated at a zero discount rate from this point forward. Three reasons lie behind this choice. First, many signing incentives are calculated using Equation 5.2, which implicitly assumes a zero discount rate. Second, many lease contracts provide tenants with options for distributing incentive payments and do not disclose which option was chosen; a zero discount rate conservatively estimates this choice. Higher discount rates penalise tenants for delaying

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[7] There is an embedded assumption that operating cost inflation can be estimated identically to face rent inflation. If operating cost inflation is significantly higher than rent inflation, there should be no effect on the results because all lessees in both net and semi-gross contracts are liable for the payment of excess operating costs. The only situation where this assumption may pose a problem is the unlikely scenario of operating expense inflation significantly lower than the agreed fixed percentage rent inflation. In this case, a tenant in a net lease contract is able to benefit because his face rent does not include the base year operating expenses, while a tenant in a semi-gross lease sees his operating cost contribution effectively rise by the fixed percentage because it is included in his face rent. No semi-gross contract includes a clause entitling a tenant to reimbursements from the owner in the event future operating expenses are less than the base year.

their incentives, so a zero rate implies the reasonable assumption that tenants will elect to receive payments as quickly as possible. Third, models run with a zero discount rate have marginally better explanatory power, perhaps as a result of the two reasons just stated.

All independent variables remain the same as described earlier. Due to fewer observations in the subsample, specifications with the smaller submarket definitions are not presented in this part of the study. Descriptive statistics in Section 5.2.2 revealed that a few of these smaller submarkets only featured a single asset in the reduced subsample, meaning the binary variable for such a submarket deviates away from representing the value of location and towards an uncertain combination of location and unmeasured qualities of a particular asset. As will be seen in Chapter 6, models run with the smaller submarkets do not deviate notably from the results using PCA submarkets. With the same variations in $\boldsymbol{ENERGY}$ tested, only five specifications of the effective rent model are run:

Specification 1: $\boldsymbol{ENERGY}$ omitted
Specification 2: $\boldsymbol{ENERGY}$ = NABERS groupings (poor, below avg., above avg., best practice)
Specification 3: $\boldsymbol{ENERGY}$ = Unique NABERS Energy ratings
Specification 4: $\boldsymbol{ENERGY}$ = Natural logarithm of asset energy use
Specification 5: $\boldsymbol{ENERGY}$ = Quintiles of asset energy use

Similar to the face rent model, the estimation methodology of ordinary least squares is used for the effective rent subsample. EViews software performs the estimation of the coefficients in Equation 5.6. The floor area represented by the 340 observations in the subsample is now below 10% of the entire population, so a finite population correction is not performed. However, minor heteroscedasticity is still present, so the correction using White's heteroscedasticity-consistent standard errors is included.

5.4.2 Sample Bias

A potential error in the model of effective rent described above is sampling bias associated with eliminating 333 observations for the reason that signing incentives were not disclosed. Bias in the estimation of Equation 5.6 would occur in the event that some unobserved variable representing the benefits of disclosure (or non-disclosure) is correlated with the stochastic error in Equation 5.6. If this is the case, the error term in Equation 5.6 is actually non-stochastic and the model suffers from omitted variable bias.

A test for sampling bias is presented in this section. The probability that effective rent is observed is estimated using a selection equation. If the residuals of the selection equation are correlated with the residuals of Equation 5.6, it will be necessary to run a more advanced estimation to correct for sampling bias, such as the two-stage regression based on Heckman (1979).

5.4.2.1 Selection Equation

To test for sample bias, it is necessary to understand the potential contributors toward the bias. Whether or not signing incentives are disclosed is captured as a binary variable for each variable in the lease dataset. For every one of the 673 observations in the complete lease database, j, Equation 5.7 specifies a model of potential factors within the database that contribute to the disclosure of signing incentives. This equation will be referred to as the selection equation:

$$DISCLOSE_j = a_j + b_1 TENANT_j + \boldsymbol{b_2 MANAGER_j} + \boldsymbol{b_3 QUAL_j} + u_j \tag{5.7}$$

Dependent variable, $DISCLOSE$, is the binary variable representing disclosure. It takes a value of one if signing incentives are fully disclosed and zero otherwise. Vector variables are indicated in bold. Stochastic error from this selection equation is represented by u. The contribution of each independent variable – $TENANT$, $\boldsymbol{MANAGER}$ and $\boldsymbol{QUAL}$ – to the probability of disclosure is the estimated coefficient b. A constant term, a, is included to represent the probability of disclosure if each independent variable takes its reference value.

$TENANT$ is an independent variable that proxies tenant credit quality based on the bank guarantee disclosed in the lease contract. It represents a hypothesis that owners may be willing to offer above-market incentives to desirable tenants with good credit quality and not disclose this incentive to prevent the transaction from influencing the market. The brief discussion at the end of Section 5.3.4 argued that a reliable continuous measure of tenant quality is unavailable because owners are inconsistent when it comes to calculating the bank guarantees that proxy tenant credit quality. However, one measure of tenant quality is consistent across the entire market: the most desirable and creditworthy tenants are exempt from depositing a bank guarantee. Hence it is possible to differentiate these tenants as “institutional tenants” using a binary variable that equals one if a lease contract excludes the tenant from depositing a bank guarantee and zero otherwise. If tenant quality is a factor in the non-disclosure of incentives as hypothesised, this binary variable will be significant and negative in the selection model.

$\boldsymbol{MANAGER}$ is a vector of binary variables representing the major property managers in central Sydney. Its inclusion is based on an observation during data collection that many lease contracts are boilerplate documents drawn up by the property management firm in each asset, some of which include sections on incentives by default. Binary variables for the following major firms are included: AMP, CBRE, Colliers International, Dexus, Investa, Jones Lang LaSalle, Knight Frank, Mirvac and Stockland. Each variable takes the value of one if the lease contract specifies that firm as the primary manager of the property, zero otherwise. The reference category is “Other”, which indicates an asset not under management of the major firms listed above. In particular, the author observed that leases for properties managed by Investa include a standard clause on incentives in a typical lease contract (Figure 5.10), so the variable for properties managed by Investa is expected to be significant and positive.

$\boldsymbol{QUAL}$ is the vector of binary variables representing asset service quality ratings. Its inclusion is based on the expectation that owners of Premium-grade assets are least likely to disclose incentives, perhaps because these assets do not need to offer incentives to prospective tenants[8]. As is the case in the effective rent model, the A-grade asset variable is the reference category for the selection equation.

Because the dependent variable is binary, Equation 5.7 will be estimated by probit regression. In the results of a probit regression, a positive sign on the estimated coefficients (b) indicates the regressor increases the probability of observing signing incentives. A negative sign on the estimated coefficient indicates a reduced probability of observing incentives. Based on the discussion of the independent variables above, a positive sign is expected for assets managed by Investa and assets at the lower end of service quality. Coefficients with negative signs are expected for leases issued to institutional tenants as well as leases in Premium-grade assets.

5.4.2.2 Calculating Error Correlation

The variable of interest in the selection equation is the error term, u. Biased estimators in the model of effective rent (Equation 5.6) are likely in the event u is correlated with the error term in that equation, ε. The correlation between ε and u is denoted as $\rho_{\varepsilon u}$. Estimating $\rho_{\varepsilon u}$ is straightforward. Following the estimation of Equations 5.6 and 5.7, the error terms ε_j and u_j are captured for each observation j as the residual between the observed value of the dependent variable and its estimate in the fitted model. The correlation coefficient between the two vectors of residuals is an estimate of $\rho_{\varepsilon u}$.

The null hypothesis, which would indicate that the censored model for effective rent is unaffected by sampling bias, is $\rho_{\varepsilon u} = 0$. A rejection of this null hypothesis indicates sampling bias has an effect on the estimation of the censored model and a correction is necessary. Since $\rho_{\varepsilon u}$ as calculated above is only an estimate, it is sensible to allow a wide margin of acceptance because a

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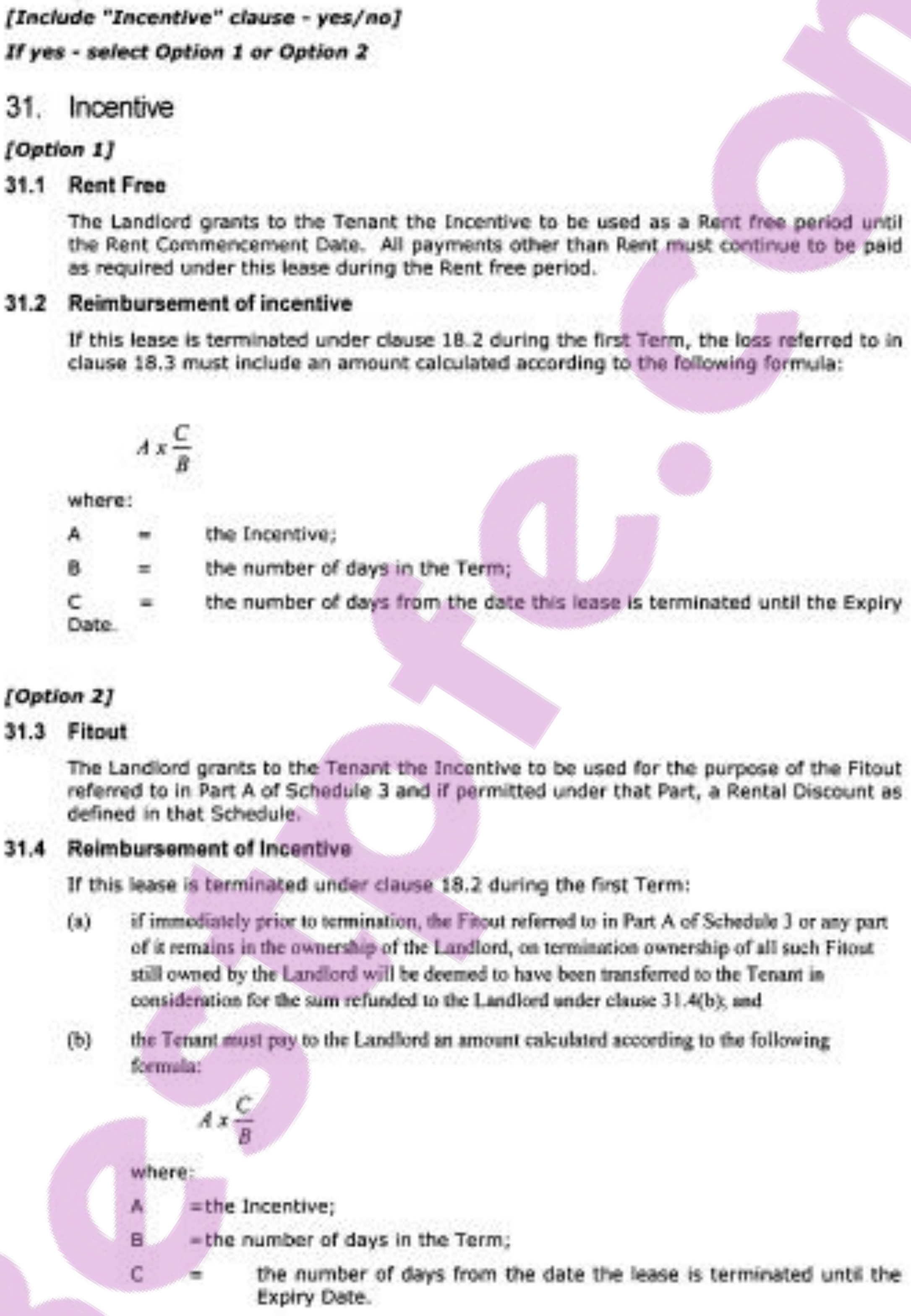
[8] Recall from Section 5.1 that any lease with no mention of incentives in the lease contract is coded as missing an incentive, since it is impossible to discern whether incentives were paid in a separate agreement.

more accurate value of $\rho_{\varepsilon u}$ is obtained when estimating the two equations simultaneously. One method of simultaneous estimation is the Heckman selection model that is widely used to control for sampling bias in censored samples.



[Include "Incentive" clause - yes/no]

If yes - select Option 1 or Option 2

31. Incentive

[Option 1]

31.1 Rent Free

The Landlord grants to the Tenant the Incentive to be used as a Rent free period until the Rent Commencement Date. All payments other than Rent must continue to be paid as required under this lease during the Rent free period.

31.2 Reimbursement of incentive

If this lease is terminated under clause 18.2 during the first Term, the loss referred to in clause 18.3 must include an amount calculated according to the following formula:

$$A \, x \, \frac{C}{B}$$

where:

A = the Incentive;

B = the number of days in the Term;

C = the number of days from the date this lease is terminated until the Expiry Date.

[Option 2]

31.3 Fitout

The Landlord grants to the Tenant the Incentive to be used for the purpose of the Fitout referred to in Part A of Schedule 3 and if permitted under that Part, a Rental Discount as defined in that Schedule.

31.4 Reimbursement of Incentive

If this lease is terminated under clause 18.2 during the first Term:

(a) if immediately prior to termination, the Fitout referred to in Part A of Schedule 3 or any part of it remains in the ownership of the Landlord, on termination ownership of all such Fitout still owned by the Landlord will be deemed to have been transferred to the Tenant in consideration for the sum refunded to the Landlord under clause 31.4(b); and

(b) the Tenant must pay to the Landlord an amount calculated according to the following formula:

$$A \, x \, \frac{C}{B}$$

where:

A = the Incentive;

B = the number of days in the Term;

C = the number of days from the date the lease is terminated until the Expiry Date.

Figure 5.10. Template for disclosure of signing incentives in a lease issued by Investa. Source: Registered Lease AF613892.

5.4.2.3 Heckman Selection Model

In the event of significant (or close to significant) correlation between the selection equation and the model of effective rent, the latter will be adjusted based on a method described by Heckman (1979). The theory behind the Heckman specification is that sampling bias can be accounted for in the original model by estimating an omitted variable with results of the selection equation. In essence, sampling bias is a specification error in an uncorrected ordinary least squares regression.

The omitted variable is the probability that an observation is selected into the subsample of effective rent observations. This probability can be estimated using the selection equation. Following estimation of the selection equation parameters, the inverse Mills ratio can be estimated for each observation (λ_j). The inverse Mills ratio is the probability density function (the likelihood that the specification equation takes the specified values observed) divided by the standard normal distribution function at the same point. The estimated inverse Mills ratio is inserted into the basic ordinary least squares hedonic regression as an additional regressor:

$$\text{Rent} = \alpha + \sum_{i=1}^{n} \beta_i X_i + \gamma G + \theta\lambda + \varepsilon \tag{5.8}$$

This transformation eliminates the correlation between ε and u, allowing consistent estimators of β and γ. The correlation between error terms is included in the estimated coefficient θ of the inverse Mills ratio. Hence if there is no correlation between residuals in the selection equation and residuals in the hedonic model, $\theta = 0$ and the original hedonic price specification results.

Traditionally, a Heckman selection model is performed in two steps; first by estimating a probit model of the selection equation and then a revised estimation of the hedonic price model with the inverse Mills ratio calculated from the selection equation. However, modern statistical software packages are able to estimate both equations simultaneously using maximum likelihood estimators, a process that is slightly more efficient than a two-step procedure (Greene, 2012). In the event that a Heckman selection model is necessary, it will be estimated by maximum likelihood using EViews software.

5.5 Summary

This chapter described the collection of data on office lease transactions in central Sydney and the specification of hedonic price models to test the relationship between rent price and asset energy consumption. A unique lease database was constructed directly from a sample of over

1,500 lease contracts registered on asset titles with the New South Wales department of Land and Property Information. Section 5.1 explained in detail how indicators were extracted directly from the contracts, other sources of data on asset characteristics and NABERS Energy disclosures to form the lease. Section 5.2 and Appendix 2 statistically describe the lease database.

In total, the Sydney lease database contains 673 transactions for office accommodation with sufficient data to quantify a series of control variables to model rent price as defined by semi-gross face rent. In Section 5.3, Equation 5.5 specifies the first hedonic price model. To comprehensively test variations in the independent variables, including 4 different representations of asset energy consumption, ten alternative constructions of the independent variables will be estimated using EViews statistical software. These estimation results are presented in the next chapter.

A small subsample of 340 transactions disclosed signing incentives to enable a second hedonic price model that specifies effective semi-gross rent as the dependent variable. Section 5.4 discussed the construction of this model (Equation 5.6). A test for sampling bias was also developed through the production of a selection model (Equation 5.7) attempting to explain why some lease contracts disclosed signing incentives and others did not disclose. Finally, a Heckman selection procedure was discussed that could correct for any significant sampling bias found in the preceding test.

Chapter 6

Sydney Lease Market Effects: Results and Conclusions

Having established a database of lease transactions for the central Sydney office market in the previous chapter and a series of econometric tests to examine the willingness of tenants to alter rent bids as a function of energy efficiency, this chapter presents and discusses the results. Section 6.1 evaluates the model specified in Equation 5.5 that examines the link between semi-gross face rent prices and four different representations of asset energy performance. Section 6.2 presents the estimation of Equation 5.6 specified to investigate whether the price of asset energy efficiency is reflected in effective rent, or the net outcome between face rent and signing incentives. Appendix 3 presents the results of other interesting subsample estimations, including net leases, semi-gross leases, prime assets, and secondary assets.

The results presented in this chapter do not find a consistent relationship between energy efficiency and rental prices for the population as a whole. Only by restricting the sample to prime assets (Premium- and A-grade assets; see Appendix 3) does the expected negative relationship between energy consumption and face rent emerge, albeit weakly. Section 6.3 asks why tenants would not be willing to pay energy efficiency rent premiums, finding trivial financial benefits and a lack of contractual obligations for Sydney tenants. The intangible benefits associated with corporate social responsibility (CSR) appear to be the primary reason for tenants to pursue energy efficient accommodation. This chapter concludes with a discussion of the implications of these findings and avenues for future research.

6.1 Semi-Gross Face Rent Results

The regression coefficients for the semi-gross face rent model on the entire population of lease transactions are presented in Tables 6.1 and 6.2. The former table presents specifications one, two, and three for each locational control variation A and B while the latter table presents specification four, specification five, and associated location control variations. Each table of results continues over multiple pages in order to comprehensively document the coefficient and adjusted *t*-value for each regressor. Hence the full estimation of specification 2A, for example, is read down the column for specification 2A across Tables 6.1a, 6.1b, and 6.1c.

Table 6.1a. Estimation of determinants of semi-gross face rent using Equation 5.5. Specifications 1, 2 and 3 only. Dependent variable is the natural logarithm of semi-gross face rent per square metre. N=673. Statistics are coefficient (t-value). ***ENERGY*** and ***LEASE*** regressors only; remaining parameters in Tables 6.1b and 6.1c.

Independent Variable	Spec. 1A	Spec. 1B	Spec. 2A	Spec. 2B	Spec. 3A	Spec. 3B
NABERS Energy Rating						
0					0.009 (0.435)	0.021 (1.043)
1					-0.038 (-1.595)	-0.047* (-1.895)
1.5					-0.011 (-0.502)	-0.007 (-0.298)
2					0.004 (0.237)	0.007 (0.454)
2.5					*Reference*	*Reference*
3					0.028* (2.035)	0.030* (2.047)
3.5					0.012 (0.910)	0.018 (1.318)
4					-0.015 (-1.073)	-0.013 (-0.942)
4.5 or 5					0.001 (0.050)	-0.005 (-0.218)
Poor (0, 1, or 1.5)			-0.011 (-0.84)	-0.009 (-0.691)		
Below Average (2 or 2.5)			*Reference*	*Reference*		
Above Average (3 or 3.5)			0.021** (2.101)	0.022* (2.018)		
Best Practice (4, 4.5 or 5)			-0.014 (-1.186)	-0.017 (-1.435)		
Oper. Expense Liability						
Net Lease	0.085*** (11.367)	0.090*** (9.029)	0.090*** (12.057)	0.090*** (9.248)	0.083*** (9.462)	0.083*** (7.657)
Semi-Gross Lease	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Lease Term Length						
Short (4 years or less)	-0.015* (-1.974)	-0.017** (-2.136)	-0.014* (-1.760)	-0.015* (-1.923)	-0.016* (-1.952)	-0.017** (-2.168)
Average (5 years)	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Long (6 years or more)	-0.023** (-2.188)	-0.023** (-2.151)	-0.021* (-2.022)	-0.021* (-2.008)	-0.022** (-2.166)	-0.022** (-2.088)
Lowest Floor Leased	0.012*** (12.915)	0.012*** (13.035)	0.012*** (12.903)	0.012*** (13.017)	0.012*** (12.758)	0.012*** (13.122)
Lowest Floor Leased Squared	-5.1x10^{-5} *** (-2.834)	-5.0x10^{-5} *** (-2.864)	-5.2x10^{-5} *** (-2.694)	-5.1x10^{-5} *** (-2.920)	-5.2x10^{-5} *** (-2.855)	5.2x10^{-5} *** (-2.96)
Leased Area (natural log)	-0.007 (-1.616)	-0.006 (-1.441)	-0.007* (-1.710)	-0.007 (-1.645)	-0.006 (-1.573)	-0.007 (-1.633)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.1b. Continuation of Table 6.1a, featuring regressor groups ***LOC*** and ***AST***. Additional parameters in Table 6.1c.

Independent Variable	Spec. 1A	Spec. 1B	Spec. 2A	Spec. 2B	Spec. 3A	Spec. 3B
PCA Submarket						
City Core	*Reference*		*Reference*		*Reference*	
Midtown	-0.115*** (-10.249)		-0.119*** (-10.648)		-0.119*** (-10.339)	
Western Corridor	-0.107*** (-11.718)		-0.109*** (-10.503)		-0.108*** (-10.065)	
Southern	-0.338*** (-13.515)	-0.339*** (-10.537)	-0.327*** (-11.964)	-0.328*** (-9.458)	-0.333*** (-11.925)	-0.343*** (-9.093)
Small Submarket						
Circular Quay		*Reference*		*Reference*		*Reference*
Chifley Square		0.008 (0.400)		0.004 (0.183)		-0.008 (-0.345)
Martin Place		-0.014 (-0.646)		-0.020 (-0.882)		-0.038 (-1.563)
Lower George Street		0.026 (1.035)		0.021 (0.796)		0.017 (0.615)
Upper George Street		-0.094*** (-3.774)		-0.110*** (-4.123)		-0.117*** (-4.206)
Hyde Park		-0.127*** (-5.363)		-0.125*** (-5.176)		-0.136*** (-5.342)
Wynyard North		-0.112*** (-5.229)		-0.122*** (-5.380)		-0.129*** (-5.496)
Wynyard South		-0.098*** (-4.314)		-0.091*** (-3.677)		-0.100*** (-3.598)
Darling Harbour		-0.086*** (-3.05)		-0.088*** (-2.957)		-0.099*** (-3.192)
Walking Distance to Train (natural log)	-0.015*** (-3.046)	-0.021*** (-3.179)	-0.013** (-2.657)	-0.019*** (-2.937)	-0.012** (-2.307)	-0.019*** (-2.854)
Asset Service Quality						
Premium	0.241*** (13.851)	0.238*** (13.064)	0.242*** (13.668)	0.240*** (13.021)	0.239*** (12.962)	0.232*** (11.958)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.090*** (-9.131)	-0.094*** (-8.800)	-0.088*** (-8.764)	-0.098*** (-9.052)	-0.092*** (-8.846)	-0.102*** (-9.547)
C-Grade	-0.403*** (-16.939)	-0.397*** (-16.082)	-0.411*** (-16.98)	-0.412*** (-16.157)	-0.415*** (-17.442)	-0.422*** (-16.138)
Asset Vintage						
Heritage (>60 years old)	0.086*** (3.273)	0.081*** (3.281)	0.097*** (3.913)	0.096*** (4.153)	0.099*** (3.860)	0.095*** (3.967)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	0.013 (0.957)	0.006 (0.443)	0.013 (0.943)	0.006 (0.442)	0.016 (1.190)	0.008 (0.565)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.1c. Continuation of Tables 6.1a and 6.1b, featuring the ***MKT*** regressors and goodness of fit metrics.

Independent Variable	**Spec. 1A**	**Spec. 1B**	**Spec. 2A**	**Spec. 2B**	**Spec. 3A**	**Spec. 3B**
Commencement Half-Year						
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	-0.001 (-0.037)	0.003 (0.131)	-0.003 (-0.123)	-0.0001 (-0.007)	-0.003 (-0.098)	0.001 (0.026)
January to June 2008	0.118*** (5.093)	0.121*** (5.232)	0.109*** (4.61)	0.111*** (4.703)	0.110** (4.583)	0.112*** (4.689)
July to December 2008	0.160*** (6.418)	0.166*** (6.691)	0.156*** (6.244)	0.162*** (6.495)	0.153*** (5.933)	0.158*** (6.174)
January to June 2009	0.153*** (6.477)	0.157*** (6.778)	0.142*** (5.899)	0.147*** (6.205)	0.144*** (5.937)	0.148*** (6.22)
July to December 2009	0.113*** (4.845)	0.119*** (5.185)	0.105*** (4.363)	0.110*** (4.589)	0.102*** (4.191)	0.106*** (4.352)
January to June 2010	0.148*** (6.83)	0.156*** (7.297)	0.141*** (6.306)	0.149*** (6.747)	0.140*** (6.153)	0.147*** (6.580)
July to December 2010	0.159*** (7.409)	0.166*** (7.844)	0.151*** (6.807)	0.159*** (7.213)	0.149*** (6.536)	0.155*** (6.886)
January to June 2011	0.176*** (7.971)	0.182*** (8.282)	0.170*** (7.463)	0.177*** (7.801)	0.171*** (7.409)	0.175*** (7.711)
July to December 2011	0.173*** (6.452)	0.179*** (6.670)	0.167*** (6.033)	0.175*** (6.348)	0.165*** (5.975)	0.172*** (6.357)
Constant	6.361*** (153.019)	6.384*** (128.177)	6.359*** (147.040)	6.391*** (127.832)	6.352*** (141.895)	6.403*** (125.413)
R-Squared	**0.869**	**0.871**	**0.872**	**0.874**	**0.873**	**0.875**
Adjusted R-Squared	**0.864**	**0.865**	**0.867**	**0.867**	**0.867**	**0.868**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Variables representing asset energy consumption reveal no consistent pattern of an energy efficiency premium, particularly as a function of the degree of energy efficiency. There is also no evidence of discounts for energy inefficient buildings. Only the subsample of prime assets in Appendix 3 weakly hints at the presence of a relationship between energy efficiency and face rent in that segmented market. As for other control variables, six characteristics consistently explain over 85% of variability in semi-gross face rent for all five specifications: tenancy floor level, asset service quality, submarket location, asset heritage, market conditions at the time of lease commencement and base-year operating expense liability. The following subsections discuss the results for each group of independent variables, beginning with the variable of interest.

Table 6.2a. Estimation of determinants of semi-gross face rent using Equation 5.5. Specifications 3 and 4 only. Dependent variable is the natural logarithm of semi-gross face rent per square metre. N=673. Statistics are coefficient (t-value). ***ENERGY*** and ***LEASE*** regressors only; remaining parameters in Tables 6.2b.

Independent Variable	Spec. 4A	Spec. 4B	Spec. 5A	Spec. 5B
Energy Consumption				
Energy Use Intensity (nat. log)	0.002 (0.159)	0.005 (0.344)		
Highest Energy Consumption Quintile (most inefficient)			*Reference*	*Reference*
2nd Energy Consumption Quintile			0.006 (0.432)	0.007 (0.565)
3rd Energy Consumption Quintile			0.016 (1.336)	0.015 (1.206)
4th Energy Consumption Quintile			-0.002 (-0.164)	-0.001 (-0.054)
Lowest Energy Consumption Quintile (most efficient)			-0.007 (-0.504)	-0.009 (-0.616)
Operating Expense Liability				
Net Lease	0.086*** (11.317)	0.089*** (8.980)	0.086*** (11.423)	0.089*** (8.984)
Semi-Gross Lease	*Reference*	*Reference*	*Reference*	*Reference*
Lease Term Length				
Short (4 years or less)	-0.015* (-1.968)	-0.017** (-2.140)	-0.014* (-1.730)	-0.015* (-1.956)
Average (5 years)	*Reference*	*Reference*	*Reference*	*Reference*
Long (6 years or more)	-0.023** (-2.187)	-0.023** (-2.155)	-0.022** (-2.093)	-0.023** (-2.142)
Lowest Floor Leased	0.012*** (12.968)	0.012*** (13.086)	0.012*** (12.771)	0.012*** (12.95)
Lowest Floor Leased Squared	-5.1x10^{-5} *** (-2.832)	-5.0x10^{-5} *** (-2.858)	-5.0x10^{-5} *** (-2.807)	-5.0x10^{-5} *** (-2.866)
Leased Area (natural log)	-0.007 (-1.625)	-0.006 (-1.459)	-0.007 (-1.701)	-0.006 (-1.489)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.2b. Continuation of Table 6.2a, featuring regressor groups ***LOC, AST, MKT*** and goodness of fit measures.

Independent Variable	Spec. 4A	Spec. 4B	Spec.5A	Spec. 5B
PCA Submarket				
City Core	*Reference*		*Reference*	
Midtown	-0.115*** (-10.21)		-0.113*** (-9.807)	
Western Corridor	-0.107*** (-10.56)		-0.102*** (-9.992)	
Southern	-0.337*** (-13.22)	-0.337*** (-10.28)	-0.329*** (-13.39)	-0.327*** (-10.15)
Small Submarket				
Circular Quay		*Reference*		*Reference*
Chifley Square		0.009 (0.413)		0.01 (0.501)
Martin Place		-0.014 (-0.642)		-0.008 (-0.353)
Lower George Street		0.026 (1.040)		0.026 (1.030)
Upper George Street		-0.094*** (-3.728)		-0.089*** (-3.535)
Hyde Park		-0.126*** (-5.294)		-0.120*** (-4.986)
Wynyard North		-0.111*** (-5.102)		-0.108*** (-4.864)
Wynyard South		-0.095*** (-3.756)		-0.086*** (-3.404)
Darling Harbour		-0.084*** (-2.932)		-0.077*** (-2.711)
Walking Distance to Train (natural log)	-0.014*** (-2.904)	-0.021*** (-3.089)	-0.013** (-2.550)	-0.018** (-2.712)
Asset Service Quality				
Premium	0.240*** (13.558)	0.237*** (12.794)	0.242*** (13.563)	0.240*** (12.879)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.090*** (-9.069)	-0.095*** (-8.536)	-0.092*** (-8.871)	-0.097*** (-8.443)
C-Grade	-0.403*** (-16.970)	-0.398*** (-16.201)	-0.406*** (-16.255)	-0.399*** (-15.339)
Asset Vintage				
Heritage (>60 years old)	0.086*** (3.291)	0.081*** (3.320)	0.084*** (3.384)	0.083*** (3.530)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	0.013 (0.970)	0.007 (0.474)	0.013 (0.937)	0.007 (0.487)
Commencement Half-Year				
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	-0.001 (-0.024)	0.004 (0.161)	-0.002 (-0.067)	0.002 (0.082)
January to June 2008	0.119*** (5.114)	0.122*** (5.276)	0.115*** (4.890)	0.118*** (4.980)
July to December 2008	0.160*** (6.470)	0.166*** (6.764)	0.159*** (6.340)	0.165*** (6.580)
January to June 2009	0.153*** (6.484)	0.159*** (6.812)	0.150*** (6.273)	0.155*** (6.563)
July to December 2009	0.113*** (4.789)	0.120*** (5.137)	0.111*** (4.630)	0.117*** (4.918)
January to June 2010	0.149*** (6.822)	0.157*** (7.303)	0.149*** (6.734)	0.156*** (7.132)
July to December 2010	0.160*** (7.361)	0.168*** (7.823)	0.160*** (7.247)	0.167*** (7.611)
January to June 2011	0.177*** (7.957)	0.183*** (8.287)	0.178*** (7.850)	0.183*** (8.097)
July to December 2011	0.173*** (6.431)	0.180*** (6.668)	0.174*** (6.366)	0.181*** (6.537)
Constant	6.344*** (55.698)	6.346*** (50.674)	6.348*** (150.71)	6.367*** (124.92)
R-Squared	**0.869**	**0.871**	**0.870**	**0.872**
Adjusted R-Squared	**0.864**	**0.865**	**0.864**	**0.865**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

6.1.1 Asset Energy Consumption

For the Sydney office market as a whole, there is no consistent signal that asset energy efficiency is associated with semi-gross face rent prices. Specifications 4 and 5 (Table 6.2a) represent asset energy efficiency with audited energy consumption data available to prospective tenants at the time of lease. None of these parameters are near the thresholds for statistical significance. If it was even possible to extract a narrative out of these insignificant energy coefficients in both specifications, that story would reflect that rent and asset energy consumption are positively related; higher energy consumption delivers higher rental income.

Measuring the relationship between asset energy efficiency and face rent using NABERS Energy ratings (Table 6.1a) tells a similar story of inconsistency, despite some parameters reaching low levels of statistical significance. Relative to the rating representing the market average (2.5 stars), the model would suggest that assets slightly above average gain a small premium based on energy efficiency. However, the coefficients as a group reveal an inconsistent relationship between energy efficiency and face rent; for example, the lowest rated cohort (0 stars) has one of the highest energy-based rent premiums, although it is statistically indistinct from zero. The most logical conclusion to such noisy data is that there is no relationship between energy efficiency – as measured by NABERS Energy ratings or audited consumption at the time of lease – and the semi-gross measure of face rent for the entire population of lease transactions. The null hypothesis cannot be rejected. As for the few variables that demonstrate statistical significance, it is likely that the particular star rating is accidentally serving as an instrument for an unobserved characteristic shared by that cohort of lease transactions.

6.1.1.1 Potential sources of error

Could a specification error or multicollinearity affecting the variables of interest be masking the hypothesised energy-rent relationship? The reason four specifications of ***ENERGY*** were produced was to control for the possibility that a binary variable could represent an unknown and unmeasured effect as an instrument by accident; based on inconsistency, this appears to be the case in lease transactions for 3-star rated assets. The remaining NABERS Energy binary variables, the continuous variable of energy consumption and associated quintile bands support the null hypothesis related to the lack of a relationship between energy and semi-gross face rent. On the other hand, the estimation of all other control variables in the model is consistent in sign and magnitude as the energy variables are removed or altered, further supporting the null hypothesis.

As for multicollinearity, its effect is not to bias the coefficients, but make estimation of them inefficient by inflating standard errors (Belsley *et al.*, 1980). The consistency of all other control variables besides ***ENERGY*** is a sign that, if any multicollinearity is present, introducing the energy variables is not adding any new information to the model. Although it should not affect the conclusion that there is no relationship between energy efficiency and semi-gross face rent for the entire population, tests for multicollinearity are performed and find some evidence of multicollinearity affecting the most energy efficient assets.

Table 6.3 displays the variance inflation factors (VIF) for each coefficient of interest across all ten model specifications. VIF measures the degree of error inflation as a result of near dependency between two or more variables (see Section 4.1.5); values above 5 mean the standard error is more than doubled as a result of interactions between two or more variables. Three coefficients of interest in Table 6.3 do show these high VIF values, and they are all related to assets with a very high measure of energy efficiency (NABERS Energy ratings of 4.5 or the lowest energy consumption quintile in specification five). Multicollinearity does not appear to be a problem with the remaining coefficients associated with asset energy consumption.

Table 6.3. Variance Inflation Factors (VIF) for independent variables of interest from Tables 6.1 and 6.2. VIF values greater than 5 indicated in bold type.

Specification	2A	2B	3A	3B	4A	4B	5A	5B
NABERS Energy Rating								
0			1.951	2.130				
1			1.441	1.564				
1.5			1.575	1.723				
2			2.727	2.729				
2.5			*Ref.*	*Ref.*				
3			3.779	4.529				
3.5			2.911	2.874				
4			3.565	3.840				
4.5 or 5			**6.424**	**10.72**				
Poor (0, 1, or 1.5)	1.695	1.719						
Below Average (2 or 2.5)	*Ref.*	*Ref.*						
Above Average (3 or 3.5)	2.511	3.119						
Best Practice (4, 4.5 or 5)	3.360	4.118						
Energy Consumption								
Energy Use Intensity (natural log)					2.161	2.818		
Top Consumption Quintile (least energy efficient)							*Ref.*	*Ref.*
2nd Consumption Quintile							2.840	2.910
3rd Consumption Quintile							2.582	2.849
4th Consumption Quintile							2.976	3.230
5th Consumption Quintile (most energy efficient)							4.820	**6.029**

To explore the nature of the multicollinearity in these energy efficient assets, a probit estimation on each of the three independent variables with VIF values above 5 is performed. This model takes the form:

$$ENERGY = \boldsymbol{\beta_1 LEASE} + \boldsymbol{\beta_2 AST} + \boldsymbol{\beta_3 LOC} + \boldsymbol{\beta_4 MKT} + \varepsilon \tag{6.1}$$

where the independent variable with high VIF becomes the dependent variable, regressed on all other independent variables in the original equation (5.5). A probit estimation is necessary because the dependent variable is binary. Maximum Likelihood estimation is used to generate the coefficients for each independent variable. These coefficients, $\boldsymbol{\beta_1}$, $\boldsymbol{\beta_2}$, $\boldsymbol{\beta_3}$ and $\boldsymbol{\beta_4}$, reflect the degree to which another independent variable in the original model contains the information added via the binary energy variable of interest, either in a positive relationship (positive coefficient) or a negative relationship (negative coefficient). A "pseudo-R squared" measure of fit for this probit model is calculated based on the assumption that the log-likelihood of a perfect fit – i.e. *ENERGY* is fully explained by the right-side variables – would be zero and the log-likelihood of the right-hand side of Equation 6.1 being constant is the lowest possible value, thus:

$$Pseudo\ R^2 = \frac{\ln \mathcal{L}(ENERGY|\alpha) - \ln \mathcal{L}(ENERGY|\boldsymbol{LEASE}, \boldsymbol{AST}, \boldsymbol{LOC}, \boldsymbol{MKT})}{\ln \mathcal{L}(ENERGY|\alpha)} \tag{6.2}$$

where $\ln \mathcal{L}(ENERGY|\alpha)$ represents the log-likelihood that the *ENERGY* variable of interest is represented by a constant-only model and $\ln \mathcal{L}(ENERGY|\boldsymbol{LEASE}, \boldsymbol{AST}, \boldsymbol{LOC}, \boldsymbol{MKT})$ represents the log-likelihood that the *ENERGY* variable is explained by Equation 6.1. If *ENERGY* is perfectly described by the right-hand side variables in Equation 6.1, its log-likelihood will equal zero, giving a pseudo-R squared value of 1. On the other hand, if the right-hand side variables provide as much information to describe *ENERGY* as a constant, pseudo-R squared will equal 0.

Results of the probit estimation on the candidates for multicollinearity are presented in Table 6.4. All non-***ENERGY*** regressors from Equation 5.5 were included in the estimation of Equation 6.1, but only those that are statistically significant are presented for ease of interpretation. If a regressor does not appear in Table 6.4, it was not a significant in explaining the outcome of the binary variable tested.

The most consistent relationship responsible for multicollinearity is a signal of spatial autocorrelation. Lease transactions in energy efficient assets are more likely to be located in the PCA submarkets of Western, Southern and Midtown than in the City Core. More specifically, these assets are located in the Wynyard South and Darling Harbour areas of the Western submarket and the Hyde Park precinct in the Midtown submarket. However, consistent estimators of marginal locational value across all ten face rent model specifications, including the control, indicate the face rent model has more than enough information to enable it to extract the marginal value of each submarket location. The spatial autocorrelation is likely indicating that 4.5 star leases are located in only a few large assets.

Table 6.4. Probit results following Equation 6.1 for independent variables of interest with VIF values above 5. Only regressors with statistically significant coefficients are displayed.

Model Specification	**3A**	**3B**	**5B**
Dependent Variable	NABERS 4.5 Stars and Up	NABERS 4.5 Stars and Up	EUI 5th Quintile
VIF in Table 6.3	6.424	10.723	6.029
N (Dependent Variable = 1)	52	52	132
Commencement Half-Year			
January to June 2008	0.074 (0.771)	0.042 (0.865)	-1.079** (0.423)
July to December 2008	1.450* (0.779)	1.441 (0.830)	-0.348 (0.417)
January to June 2009	1.386 (0.847)	1.956* (1.036)	-0.478 (0.466)
July to December 2010	1.978*** (0.704)	2.356*** (0.836)	-0.088 (0.365)
Lease Term Length			
Long (6 years or more)	0.796* (0.408)	0.782 (0.484)	-0.090 (0.204)
Asset Vintage			
Heritage (>60 years old)	0.495 (0.763)	1.871* (1.036)	1.409*** (0.404)
Operating Expense Liability			
Net Lease	1.933*** (0.389)	1.180** (0.463)	-0.025 (0.165)
PCA Submarket			
Midtown	1.099** (0.519)		
Western Corridor	2.121*** (0.490)		
Southern	4.835*** (0.840)	6.204*** (1.296)	1.933*** (3.829)
Small Submarket			
Hyde Park		2.843*** (0.919)	0.975*** (0.250)
Wynyard South		4.395*** (1.004)	2.604*** (0.282)
Darling Harbour		2.904** (1.359)	2.144*** (0.376)
Walking Distance to Train (natural log)	-0.334* (0.174)	-0.361* (0.214)	-0.118 (0.081)
Asset Service Quality			
Premium	1.136* (0.656)	1.749* (0.895)	-0.117 (0.284)
B-Grade	1.558*** (0.428)	0.861* (0.508)	-0.680*** (0.199)
C-Grade	None in Sample	None in Sample	None in Sample
Leased Area (natural log)	-0.834*** (0.150)	-0.964*** (0.213)	-0.110* (0.059)
Log-Likelihood	**-62.99**	**-52.207**	**-233.42**
Log-Likelihood (constant only)	**-183.08**	**-183.08**	**-333.13**
Pseudo-R Squared	**0.656**	**0.715**	**0.299**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

As explained earlier, the degree of multicollinearity seen in Table 6.3 leads to an inefficient estimation of the standard error for the energy variables. Table 6.4 reveals that, according to the pseudo-R squared metric, the model "sees" that only 29 to 34% of the information it receives from the NABERS 4.5 star variable is unique, depending on the specification. This means it can estimate the effect of the energy rating, but is less confident of its significance because of an effectively reduced sample size. In summary, observed multicollinearity should not affect the conclusion that there is no relationship between energy consumption and semi-gross face rent across the entire population because even if the coefficients of the variables of interest were significant, the story they tell is not one of a consistent relationship between energy efficiency and rent.

6.1.1.2 Market segmentation

Appendix 3 presents estimations of Equation 5.5 using some intentionally biased samples of the population to investigate whether a particular segment of the Sydney office market values asset energy efficiency. The estimation of only prime assets (Premium- and A-grade quality ratings; Table A.9) produces the expected negative relationship between asset energy consumption and semi-gross face rent. Most revealing was a significant and negative coefficient (-0.05) for the measure of raw energy consumption in specification four. Because this coefficient is measuring the natural logarithm of energy consumption, its interpretation is an elasticity: for every one percent increase in energy consumption, semi-gross face rent decreases 0.05 percent in prime asset tenancies.

On the other side of the market, secondary assets have a *positive*, but statistically insignificant, relationship between asset energy consumption and semi-gross face rent (Table A.10). The reason behind this is hypothesised in Appendix 3 as the potential for energy consumption to proxy the degree of partial provision for prime asset services in secondary assets. In other words, energy efficient secondary assets use less energy because they provide fewer services, not because they provide a standard level of services using less energy inputs.

In summary, there are weak signs that tenant demand for asset energy efficiency varies according to whether that tenant is in the prime or secondary market. But when combined, these two markets counteract each other to reveal a lack of an overall relationship between energy efficiency and rent. Characteristics that consistently determine the price of semi-gross face rent are found in the control variables that follow.

6.1.2 Lease Contract Characteristics

Four groups of indicators make up the ***LEASE*** vector variable: tenancy height, the operating expense liability clause, tenancy area and lease term length. With the exception of tenancy area, each of these indicators is a significant contributor to semi-gross face rent. This is a surprise for the operating expense liability clause variable, which was expected to have no effect on face rent in a competitive market. As for the other three groups of indicators, the relationship between the variables and face rent was as expected from the discussion in Chapter 5.

6.1.2.1 Tenancy Height

The height of the tenancy in each lease contract is one of the strongest determinants of semi-gross face rent, with *t*-values well above 10 in each specification. Figure 5.1 depicted a lease contract with a linear positive relationship between tenancy height and semi-gross face rent and the model of Equation 5.5 verified that this is a common practice. Although tenancy height is represented as a quadratic polynomial, only the highest assets see diminishing returns to tenancy height; with three orders of magnitude between the polynomial coefficients, the trend is effectively linear up until the 30th floor. Figure 6.1 plots the modelled polynomial relationship up to the 80th floor based on the results of Specification 1A.

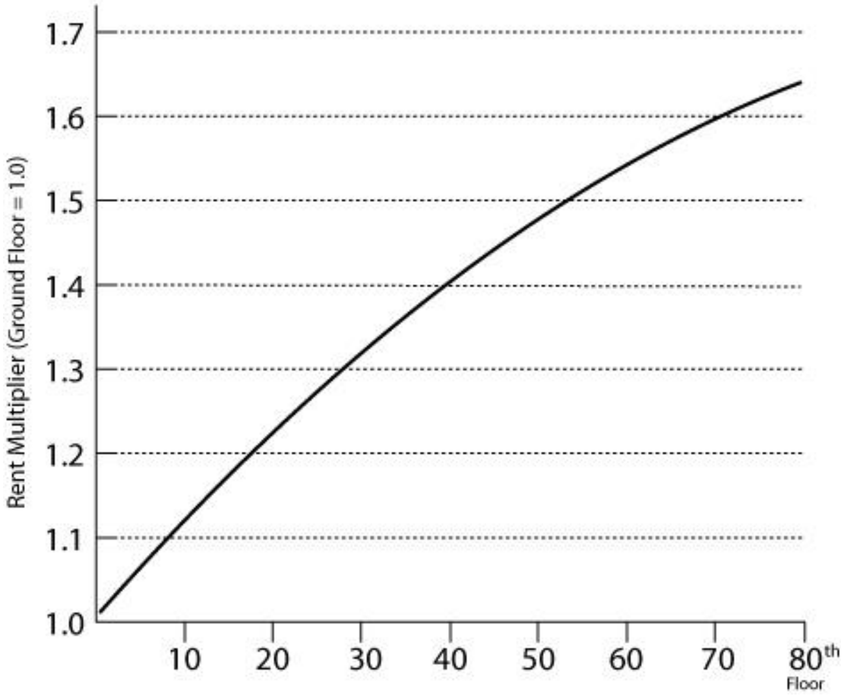


Figure 6.1. Modelled relationship between tenancy floor height and semi-gross face rent.

6.1.2.2 Operating Expense Liability

The strong and consistent rent premium for net lease structures relative to semi-gross lease structures is a surprise result from Tables 6.1 and 6.2. Recall that the only theoretical difference between a net lease and a semi-gross lease is the method of payment for base year operating expenses; in a semi-gross contract, this base year payment is included in the face rent while a net contract requires the tenant to make a separate monthly payment to the owner for base year expenses. Both contract structures assign the tenant liability for the payment of increases over the base year. However, the model is suggesting that when estimated base year operating expense payments are added to net face rent to create a semi-gross equivalent, tenants in a net lease contract pay approximately 9% higher rent, all else equal.

In overseas office markets, such as the United States, there is an expected difference between the value of net and gross lease contracts because the structure is used to determine which party bears the risk of cost increases (Wiley, forthcoming). Rent premiums in these markets are expected for gross leases as payment to the owner for assuming the risk of cost increases. But in Sydney, there is not a common commercial office lease structure that matches a full gross lease placing the risk of operating cost increases on the owner[1]. However, a Sydney office tenant would be better off in a net lease contract in the unlikely event operating cost inflation falls well below the percentage assigned to annual rent increases because semi-gross tenants will automatically have their base year operating expense payment inflated by the fixed percentage. Could this be the reason for a net lease premium? Not likely, because a look at the Property Council of Australia (2006a, 2008a, 2009, 2010) annual survey of operating cost benchmarks in the central Sydney office market during this study period reveals a steady increase in office operating costs well above the 4% inflation assigned to most annual rent reviews. Hence it would be very illogical for an office tenant to pay a 9% face rent premium for the unlikely possibility that operating costs plunge enough to justify such an investment.

Following discussions with the industry in Sydney, the author has developed two hypotheses for the surprising net lease rent premium that are useful for developing future research. One is the reason why a variable representing lease structure was included in the model specification: professional valuers in Sydney do not use net lease contracts plus base year operating expense payments as a comparable transaction when estimating market rent for a semi-gross lease, and vice-versa. This practice belies the possibility of market segmentation, which is evidently quite strong.

Standard valuation practice alludes to the possibility for a gap between net and semi-gross lease prices when expressed as a common measure of rent, but it falls short of explaining why a net lease premium perpetuates in a competitive market. This produces some future research opportunities. Why are owners of assets with a semi-gross lease structure unable to secure

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[1] More precisely, there are no contracts in the lease database outside of the traditional net and semi-gross structures. The requirement for an asset to be NABERS Energy rated in order for its leases to be included in the database may exclude full-service gross leases. In order to obtain a NABERS Base Building Energy rating, an asset must be able to separate energy consumption from base building services and consumption from individual tenancies. Owners of assets without the ability to split energy consumption between tenants and base building services may be the most likely to consider full-service gross leases to avoid disputes when trying to distribute costs between multiple tenancies.

tenants at 9% higher rental rates? Conversely, why are tenants signing a net lease not able to negotiate a 9% discount or simply ask for a semi-gross contract?

The second possibility to be explored in further research is that the net lease variable in this study is a proxy for an asset quality not captured in the service quality variables. Asset owners are not usually willing to have a mix of net and semi-gross contracts, so each owner deals with net or semi-gross structures exclusively. Appendix 2 shows that Premium-grade asset owners nearly all use net lease contracts, so there could be some unmeasured asset characteristic not captured in an asset quality rating that is associated with the decision to use net or semi-gross contracts. This possibility, along with the effect of professional valuation practices, should be assessed in future research.

6.1.2.3 Lease Term Length & Tenancy Area

The model shows a consistent pattern in regard to expected discounts for lease contract durations away from the typical lease term of five years. Tenants willing to commit to longer contracts are offered slight discounts of approximately 2% off semi-gross face rent, all else being equal. On the other side, owners desperate for tenants offer a 1.5% discount to tenants willing to sign short-term contracts.

Lastly, the hypothesised economy of scale for large tenancy areas emerges in the coefficient for tenancy area, but it is small and statistically insignificant from zero. The model estimates that every 1% increase in floor area leased to a tenant is rewarded with a 0.007% discount in semi-gross face rent per square metre. Two reasons explain why the model does not show a stronger signal for an economy of scale. First, in this study, one lease contract represents one observation. When size is of interest, there are necessarily going to be more lease contracts for smaller tenancies than large tenancies. If discounts are only offered to the few large tenancies in the database, these discounts are likely drowned out by the consistency of rental rates for small increases in area amongst the smaller tenancies. If some form of weighting is applied to the database based on floor area, a stronger relationship between tenancy size and floor area may emerge. Second, operating expenses are always the same for each tenant in an asset, no matter how large the tenancy, so the need to use semi-gross rent as the common measure of rent slightly dampens any net rent discounts offered based on tenancy size.

6.1.3 Location Characteristics

Unsurprisingly, location within central Sydney has a large effect on the price of office rent. Although location was not the variable of interest in this study, Chapter 5 presented two variants of submarket definitions: the traditional PCA submarkets as well as a more refined delineation of “smaller” submarkets. PCA submarkets were used in every specification labelled with an “A” and the smaller submarkets used in every specification labelled with a “B”. The PCA Southern submarket did not have sufficient observations to break up into smaller submarkets; hence it appears in all ten specifications.

The parameter estimations in each model featuring the PCA submarkets are as expected based on the author’s knowledge of the Sydney market. As the reference category, the City Core was expected to have the highest rents. The negative and highly significant coefficients for Western, Midtown and Southern submarkets confirm this expectation. Furthermore, the Southern submarket was expected to have the lowest rents and the model agrees, assigning a rent discount of 40% ($e^{0.33}$) relative to the City Core consistently across all specifications. The Western and Midtown PCA submarkets are relatively equal when it comes to the relationship between location and rent, with both showing between 11-13% rent discounts relative to the City Core.

Use of the smaller submarkets adds a marginal amount of explanatory power to the model but also confirms how the market largely conforms to the PCA submarket definitions. The four smaller submarkets carved out of the City Core – Circular Quay, Martin Place, Chifley Square, and Lower George Street – are statistically indistinct from each other in regard to the effect of location on semi-gross face rent. Where the smaller submarkets add explanatory power to the model is in the breakup of the Western and Midtown PCA submarkets. In particular, the redeveloped Darling Harbour precinct has more locational value, with the highest rents outside of the City Core area, than the other districts carved out of the Western PCA submarket. As one travels north in the former Western submarket, away from Darling Harbour, face rents decline. Similarly, within the Midtown PCA submarket, rents appear to be related to the distance from Sydney’s most popular commercial street (George Street). The Upper George Street submarket is shown to have higher rents than the Hyde Park submarket that represents the part of Midtown furthest from George Street.

Distance to rail transit is a significant contributor to semi-gross face rent. For every 1% increase in walking distance away from a rail station, face rent declines approximately 0.015 to 0.02%. While the scale in this study (central Sydney) is much smaller than the entire country of the Netherlands used by Kok and Jennen (2012) in their study on the effect of rail transit on lease face rent, the outcome of the relationship between distance to rail transit and face rent is similar. In the context of this study, distance to rail transit helps to refine locational premiums within each submarket.

6.1.4 Asset Characteristics

Asset quality ratings are strongly associated with semi-gross face rent. Providing the services required for a Premium-grade rating results in a semi-gross face rent approximately 27% ($e^{0.24}$) higher than an equivalent asset providing A-grade services. On the other side, B-grade assets offer a discount of approximately 10% relative to A-grade services and C-grade assets must offer very large rent discounts; on average, semi-gross face rent in a C-grade asset is half ($e^{0.41}$) the equivalent rent in an A-grade asset, all else being equal. The C-grade parameters are the strongest in the entire model, with *t*-values above 15. These quality rating parameters are consistent across all ten model specifications, reveal the expected impact of quality on face rent and, judging from their statistical power, very important in the determination of face rent. Therefore, European models of lease transactions (Chegut *et al.* 2012; Fuerst *et al.* 2013) are almost certainly suffering from an omitted variable bias due to the lack of agreed definitions of asset quality in Europe.

Vintage also has the expected effect within the context of its inclusion along with asset quality ratings. The few historic and culturally significant assets over 60 years old reveal the expected premium in semi-gross face rent that reflects demand for a scarce resource. Rents in heritage assets are approximately 9% higher than assets built in the post-war construction boom 30 to 60 years ago. Newer assets less than 25 years old do not show a statistically significant premium, most likely because the features that would drive a young vintage premium – technology, for example – are accounted for in the asset quality rating variables. The effect of any service renovations would also be accounted for in the asset quality variables.

6.1.5 Fixed Market Characteristics

The series of half-year variables in Tables 6.1 and 6.2 track the market cycle very well. Figure 6.2 plots the rent multipliers from this study against an index created with average face rent data by half-year from Colliers International Research (2012)[2]. In this study, there is a remarkably good fit between the two indices. The peak of the pre-Global Financial Crisis boom occurs in the July-December 2008 half year, followed by a short slump and slow recovery. Data from Colliers International is of net face rent, not semi-gross face rent, demonstrating the strong correlation between the two measures.

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[2] Colliers International Research reports three "average" net face rent indicators every half year, one for Premium-grade assets, one for A-grade assets and one for B-grade assets (see Figure 5.4 for an example). A whole-market average face rent is created through a weighted average using the square metres of stock in each quality category that is published in the same report. To create the index, the whole-market average net face rent for January-June 2007 is set at 1.0 to match the methodology in this study.

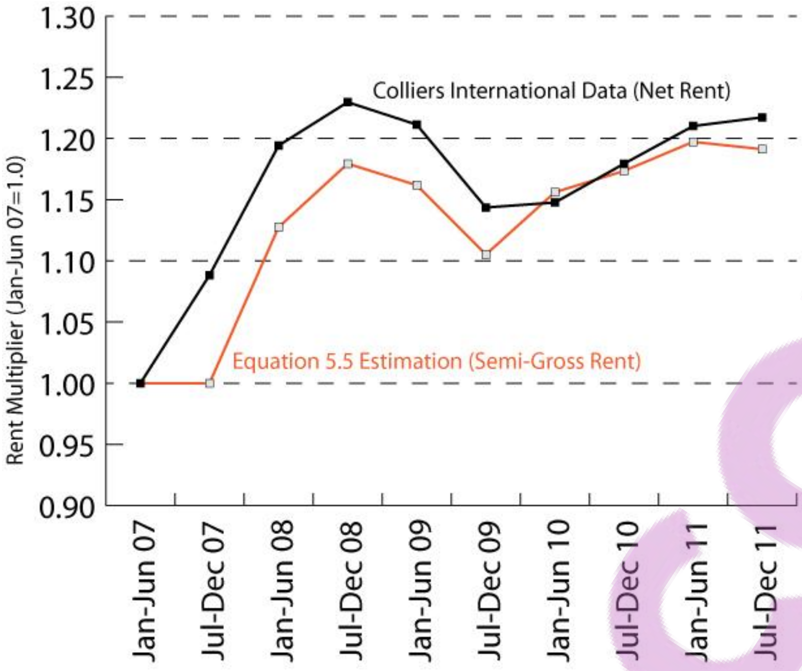

Figure 6.2. Comparing results from this study and a report from Colliers International (2012) on the market trend for average face rents in central Sydney.

6.1.6 Overall Conclusions of the Semi-Gross Face Rent Model Estimations

Six characteristics in Tables 6.1 and 6.2 explain over 85% of variability in face rent prices in all ten specifications. First, the vertical location of the tenancy within the building has a significant impact on face rent; higher floors attract higher semi-gross face rent relative to lower floors. Second, tenancies in buildings graded "Premium" have the highest semi-gross face rents while B- and C-grade buildings offer discounts of approximately 11% and 50% relative to A-grade buildings. Third, the value of submarket location produces expected results; the highest rents are in the prime City Core precinct while a statistically equivalent building in the less desirable Southern precinct rents for approximately 40% less. Redefining smaller submarket boundaries led to a marginal improvement in differentiating Western and Midtown submarket location effects. Distance to rail transit helps refine intra-submarket location effects. Fourth, the limited supply of heritage assets increases semi-gross face rents as expected. Fifth, market fixed effects variables had the expected pattern regarding the effect of the global financial crisis, with semi-gross face rents rising during 2007 and 2008, falling in 2009 and slowly rising afterwards. Finally, the sixth major influence on the leasing market in Sydney is surprising. The variable for operating expense liability indicates tenants on net rental contracts pay approximately 9% more in semi-gross rental costs than those on semi-gross rental contracts, all else equal.

The addition of asset energy performance characteristics does not consistently add to the explanatory power of the model like the six characteristics described above. The only approach that generates a weak relationship between energy efficiency and face rent was to discard all secondary grade assets, meaning that energy efficiency is valued only in the subset of prime grade tenants. The lack of consistency in the population as a whole leads to the conclusion that there is no general relationship between energy efficiency and face rent, which represents a failure to reject the null hypothesis proposed in Chapter 5.

The next section relaxes the assumption that signing incentives are a fixed market effect and asks whether the expected negative relationship between energy consumption and face rent emerges for the whole population when calculating the effective rent that tenants pay for office accommodation in Sydney. Perhaps the benefit of energy efficiency to asset owners is reflected in lower signing incentives needed to secure tenants.

6.2 Effective Rent Models

The previous chapter specified a model of effective rent in Equation 5.6. The model is nearly identical to the semi-gross rent model presented above, but with two key changes. First, the dependent variable becomes the natural logarithm of semi-gross effective rent, which is an annual level payment representing the net present value of all cash flows specified in a lease contract relating to office accommodation (face rent, operating expenses, face rent increases and signing incentives). Section 5.2.2 describes the calculation of effective rent in more detail. The second change is the loss of nearly half the lease database because signing incentives are often omitted from the registered lease contract that is the primary source of transaction data in this study.

Tables 6.5a and 6.5b presents the full estimation of Equation 5.6 using the 340 observations that disclose sufficient data to calculate effective rent. The smaller submarket delineations are not used because the small sample size increases the chances of spatial autocorrelation (as seen in Table 6.3) with very little benefit in increased explanatory power. As seen in the face rent model above, the PCA submarket definitions account for locational attributes in the Sydney office market very well.

The expected negative relationship between energy consumption and effective rent does not emerge in the estimation of Equation 5.6. Once again, the coefficients of specifications four and five are insignificant from zero and if they could tell a story, it would be one of a positive relationship between energy consumption and effective rent.

Table 6.5. Estimation of determinants of semi-gross effective rent using Equation 5.6. Dependent variable is the natural logarithm of semi-gross effective rent per square metre. N=340. Statistics are coefficient (t-value). ***ENERGY*** and ***LEASE*** regressors only; remaining parameters in Tables 6.6.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			-0.02 (-0.528)		
1			-0.057 (-1.215)		
1.5			-0.027 (-0.640)		
2			0.001 (0.039)		
2.5			*Reference*		
3			-0.016 (-0.608)		
3.5			-0.008 (-0.271)		
4			-0.059** (-2.03)		
4.5 or 5			-0.054 (-1.387)		
Poor (0, 1, or 1.5)		-0.030 (-1.090)			
Below Average (2 or 2.5)		*Reference*			
Above Average (3 or 3.5)		-0.014 (-0.763)			
Best Practice (4, 4.5 or 5)		-0.059** (-2.40)			
Energy Consumption					
Energy Use Intensity (natural log)				0.012 (0.347)	
Top Consumption Quintile (least energy efficient)					*Reference*
2nd Consumption Quintile					0.046 (1.556)
3rd Consumption Quintile					0.032 (1.267)
4th Consumption Quintile					0.017 (0.575)
5th Consumption Quintile (most energy efficient)					-0.014 (-0.451)
Oper. Expense Liability					
Net Lease	0.134*** (8.203)	0.146*** (8.530)	0.144*** (6.573)	0.136*** (7.694)	0.140*** (8.066)
Semi-Gross Lease	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Lease Term Length					
Short (4 years or less)	-0.063*** (-4.398)	-0.056*** (-3.681)	-0.056*** (-3.614)	-0.064*** (-4.358)	-0.058*** (-3.860)
Average (5 years)	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Long (6 years or more)	0.030 (1.335)	0.037 (1.644)	0.038 (1.681)	0.030 (1.341)	0.033 (1.481)
Lowest Floor Leased	0.009*** (5.098)	0.008*** (4.643)	0.008*** (4.564)	0.008*** (5.091)	0.008*** (4.973)
Lowest Floor Leased Squared	$-1.3\text{x}10^{-5}$ (-0.471)	$-2.7\text{x}10^{-6}$ (-0.095)	$-2.9\text{x}10^{-6}$ (-0.100)	$-1.2\text{x}10^{-5}$ (-0.436)	$-1.2\text{x}10^{-5}$ (-0.446)
Leased Area (natural log)	-0.011 (-1.508)	-0.011 (-1.406)	-0.010 (-1.335)	-0.011 (-1.531)	-0.011 (-1.447)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.6. Continuation of Table 6.5, featuring regressor groups ***LOC, AST, MKT*** and goodness of fit measures.

Independent Variable	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**	**Spec. 5**
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.137*** (-4.750)	-0.132*** (-4.481)	-0.130*** (-4.412)	-0.137*** (-4.726)	-0.126*** (-4.148)
Western Corridor	-0.123*** (-7.884)	-0.102*** (-5.156)	-0.103*** (-4.627)	-0.119*** (-6.303)	-0.103*** (-5.134)
Southern	-0.291*** (-3.607)	-0.263*** (-3.299)	-0.265*** (-3.294)	-0.285*** (-3.480)	-0.254*** (-3.103)
Walking Distance to Train (natural log)	-0.005 (-0.428)	-0.007 (-0.589)	-0.007 (-0.591)	-0.005 (-0.413)	-0.004 (-0.385)
Asset Service Quality					
Premium	0.301*** (8.642)	0.294*** (8.652)	0.291*** (8.319)	0.299*** (8.544)	0.299*** (8.478)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.152*** (-7.715)	-0.140*** (-6.666)	-0.141*** (-6.065)	-0.151*** (-7.593)	-0.143*** (-6.850)
C-Grade	-0.413*** (-10.083)	-0.420*** (-10.083)	-0.418*** (-9.069)	-0.413*** (-10.048)	-0.415*** (-9.955)
Asset Vintage					
Heritage (>60 years old)	0.208*** (4.637)	0.183*** (3.890)	0.185*** (3.832)	0.208*** (4.637)	0.192*** (4.143)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	-0.024 (-0.993)	-0.019 (-0.753)	-0.016 (-0.646)	-0.024 (-0.979)	-0.023 (-0.937)
Commencement Half-Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	-0.015 (-0.382)	-0.022 (-0.533)	-0.027 (-0.642)	-0.014 (-0.351)	-0.028 (-0.675)
January to June 2008	0.153*** (4.251)	0.142*** (3.614)	0.136*** (3.543)	0.155*** (4.288)	0.137*** (3.519)
July to December 2008	0.236*** (6.351)	0.230*** (5.965)	0.223*** (5.839)	0.237*** (6.347)	0.223*** (5.793)
January to June 2009	0.175*** (4.779)	0.166*** (4.250)	0.161*** (4.097)	0.177*** (4.785)	0.157*** (4.030)
July to December 2009	0.038 (1.091)	0.035 (0.930)	0.029 (0.772)	0.04 (1.155)	0.027 (0.716)
January to June 2010	0.075** (2.248)	0.075** (2.062)	0.070* (1.935)	0.078** (2.276)	0.069* (1.907)
July to December 2010	0.101*** (3.082)	0.098*** (2.771)	0.091** (2.581)	0.104*** (3.080)	0.093*** (2.616)
January to June 2011	0.101*** (2.732)	0.105*** (2.723)	0.100*** (2.634)	0.103*** (2.735)	0.095** (2.459)
July to December 2011	0.123** (2.282)	0.121** (2.238)	0.114** (2.082)	0.124** (2.335)	0.113* (1.948)
Constant	6.33*** (77.55)	6.346*** (76.47)	6.351*** (75.91)	6.251*** (77.29)	6.304*** (74.24)
R-Squared	**0.853**	**0.857**	**0.857**	**0.853**	**0.857**
Adjusted R-Squared	**0.842**	**0.844**	**0.842**	**0.842**	**0.844**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

A similar narrative emerges from the specifications that include NABERS Energy variables; most coefficients are insignificant and lack a consistent relationship between NABERS Energy ratings and effective rent. However, in specifications two and three, NABERS Energy coefficients for assets with best practice energy efficiency are significant and negative, suggesting effective rent discounts for energy efficiency. Section 6.2.1 below ascertains the selection bias of the effective rent subsample and indicates secondary grade assets are most likely to disclose signing incentives. Hence the negative coefficient is likely a result of this bias. Appendix 3 indicated that the secondary grade office market segment is likely to value assets with greater energy use because the level of consumption may be an indicator of partial A-grade service provision.

Overall, the non-energy control variables display the same consistency throughout all five specifications that was observed in the face rent models. However, there are a number of changes in regard to coefficient magnitude, one change in the sign of a coefficient (long-term leases), a number of coefficients that remain consistent regardless of what measure of rent is used, and a new pattern of fixed market control coefficients. The next few paragraphs explain these changes.

For asset service quality, vintage and operating expense liability the change from face rent to effective rent amplifies the effect observed in Tables 6.1 and 6.2. To use service quality as an example, an asset owner providing Premium-grade services leases space for a 35% effective rent premium relative to an owner providing A-grade services. When expressed as a face rent premium, the increase was only 27%. This pattern suggests that owners of desirable assets secure tenants with fewer incentives than an A-grade asset. In the case of B- and C-grade assets, the change to effective rent amplifies observed face rent discounts. Not only do B-grade assets lease for a discount relative to A-grade assets, their owners must offer larger incentives than A-grade assets.

The surprising net lease coefficient also behaves in this manner; effective semi-gross rent premiums for net lease contracts are consistently higher than the face rent premiums observed in Tables 6.1 and 6.2. This observation makes mathematical sense if an owner uses Equation 5.2 (or any other function of face rent) to calculate incentive amounts. Without an adjustment to semi-gross face rent for the portion representing operating expenses, owners will pay a higher incentive to semi-gross tenants if everything else, including the incentive percentage, remains equal. Although this makes mathematical sense, it suggests some owners may not make adjustments to incentives based on lease structure, either by excluding operating expenses or using a lower percentage for semi-gross incentives. Future research on the net lease premium will also need to investigate this market anomaly.

Short-term leases also follow the amplification pattern; effective rent discounts are greater than face rent discounts. On the other hand, the face rent discount offered for a long-term lease (over 5 years) disappears in the model for effective rent and is replaced with a *premium* relative to the 5-year lease. While it may be the case that desperate owners offer larger incentives and reduced face rent to tenants willing to sign short-term leases, the explanation for both observations is likely based on the zero discount rate used to calculate effective rent. While the zero discount rate assumption is useful for modelling the uncertainty of incentive distribution, it also has the effect of increasing effective rent because of negotiated rent increases. If the nominal value of negotiated rent increases exceeds the nominal value of signing incentives, the result will be higher effective rents than face rents. Since nominal face rent increases are a function of lease duration, usually an annual fixed percentage increase, long-term leases are likely to meet the criteria for an effective rent larger than face rent. This theory can also be expressed as declining returns to signing incentives as lease durations increase.

Coefficients for tenancy height, leased area and PCA submarket location are relatively consistent between the face rent and effective rent models. The lone exception in this group is the coefficient for the Southern PCA submarket, which becomes less negative. Most likely, this is a result of small sample size; the face rent model only had eight lease observations in the Southern submarket and the effective rent model only has three lease observations, making it possible for one observation to have a strong influence on the estimated coefficient.

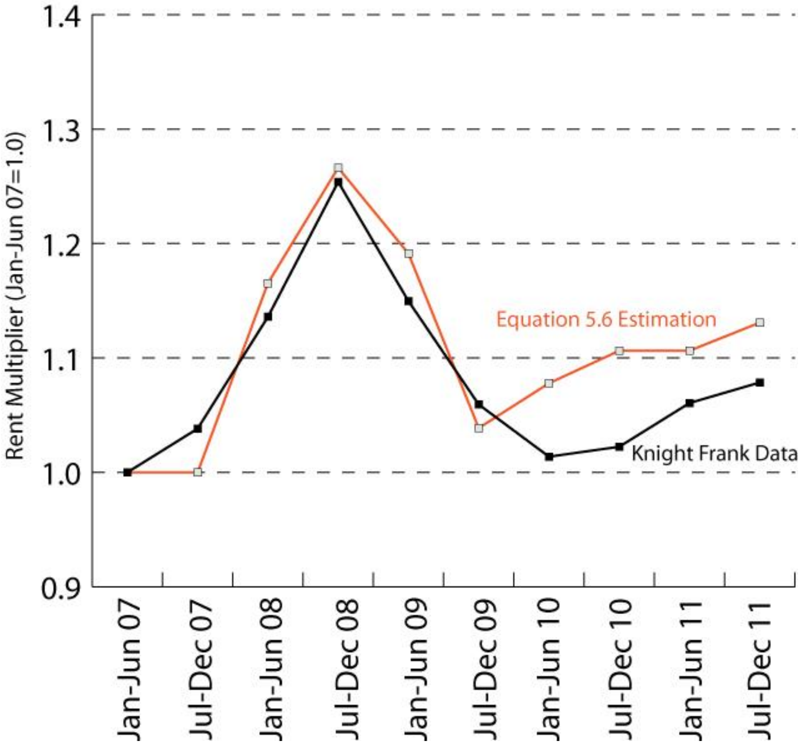

Figure 6.3. Comparing results from this study and a report from Knight Frank Research (2013) on the market trend for semi-gross effective rents in central Sydney.

Finally, there is a distinct change in the pattern of fixed market effects regarding effective rent, as one would expect if there is a strong fixed market effect associated with incentive payments. Figure 6.3 plots the market trend over time as estimated in this study along with a comparable trend of semi-gross effective rents as compiled by the property management firm Knight Frank Research (2013)[3]. As was the case with the face rent model, the estimation of fixed time effects from the sample in the lease database closely matches the externally published index. Unlike face rent (Figure 6.2), which had recovered to its pre-Global Financial Crisis (GFC) peak by the end of the time period in this study, effective rent fell much further away from its pre-GFC peak and did not fully recover. The only minor difference between the trend in this study and that reported by Knight Frank is just how far away from the peak semi-gross effective rent falls before beginning its recovery. One reason for the difference is the sampling bias accidentally introduced because the observation of signing incentives is not purely random (see Section 6.2.1). There is a slight bias towards secondary assets (B- and C-grade asset service quality). Knight Frank Research (2013) showed that effective rent in prime assets (Premium- and A-grade asset service quality) fell much further away from its pre-GFC peak than secondary assets, so the bias towards secondary assets in this study is a logical reason for the higher post-GFC recovery.

In summary, the effective rent model in this study largely conforms to the findings of the face rent model with some minor adjustments to the coefficients. These adjustments are logically explained: incentives are higher for some characteristics that associate with low face rent and lower for some characteristics that associate with high face rent; negotiated rent escalation reduces the influence of signing incentives as lease term durations rise; and the post-GFC market cycle depression is more evident when signing incentives are included. These changes support the theory that incentives are a fixed market effect and can vary based on asset characteristics. However, one characteristic that appears unrelated to both face and effective rent is a representation of energy consumption. The next section considers whether an unmeasured bias in the effective rent sample could affect the estimation of Equation 5.6.

6.2.1 Effective Rent Selection Results

The discussion regarding the results of the effective rent model addressed that sample bias could be affecting the estimated coefficients. To better understand any sampling bias, Equation 5.7 hypothesised a selection model where tenant quality, asset quality and asset management firm

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[3] Knight Frank Research reports average semi-gross face rent for prime (Premium- and A-grade assets) and secondary assets. To calculate a whole-of-market average, the semi-gross face rent reported for each half-year is the weighted average of the two figures using the total square metres of prime and secondary asset stock as published in the same report.

behaviour affects whether singing incentives are disclosed on the lease contracts obtained for this study. Table 6.7 reports the estimation of this selection equation.

Incentive disclosure is significantly related to tenant and asset quality. Desirable tenants not required to put funds in a bank guarantee for owner security are likely to have their signing incentive payments withheld from the registered lese contract. Similarly, Premium-grade building owners are not likely to disclose signing incentive payments. This latter observation could be the result of these owners not having to make incentive payments, since effective rent premiums in Premium-grade assets are higher than face rent premiums and it is impossible in this study to know if an owner paid zero signing incentives. On the other side of the quality distribution, B- and C-grade asset owners are more likely than prime asset owners to disclose incentives.

Table 6.7. Estimation of the effective rent selection equation using a probit model. Dependent variable is a binary variable representing whether signing incentives are observed (1=yes). N=673. Statistics are coefficient (*t*-value).

Independent Variable	Coefficient (Std. Error)
Tenant Exempt from Bank Guarantee (1=yes)	-0.832*** (0.152)
Asset Service Quality	
Premium	-0.519*** (0.190)
A-Grade	Reference
B-Grade	0.443*** (0.130)
C-Grade	0.593** (0.274)
Property Management Firm	
AMP	-0.296 (0.335)
CBRE	0.484** (0.224)
Colliers International	0.096 (0.312)
DEXUS	-0.288 (0.266)
Investa	1.007*** (0.208)
Jones Lang LaSalle	0.346** (0.165)
Knight Frank	-0.228 (0.185)
Mirvac	0.670* (0.380)
Stockland	-0.560 (0.358)
Other	Reference
Constant	-0.200 (0.150)
Log-likelihood	**-403.0**
McFadden R-Squared	**0.126**

In the vector of management firm variables, there are no firms with a significant tendency towards non-disclosure of incentives. Three firms – CBRE, Investa and Mirvac – have a significant positive association with the disclosure of incentives. In particular, if an asset is managed by Investa, it is highly likely to disclose incentives, matching the expectation developed while producing the lease transaction database.

With prime assets most likely to obfuscate incentives and secondary assets likely to disclose them, there may be a secondary-grade bias to the coefficients. Of most interest to this study is the effect of any bias on the energy consumption coefficients. Appendix 3 presented results for a face rent model with only secondary asset observations, noting that energy consumption and face rent show a weak positive association. Thus, the negative coefficients for high NABERS Energy ratings and the positive coefficient for asset energy consumption in the effective rent estimation may be indicative of a secondary asset bias. However, the relative consistency in coefficients representing energy characteristics when the effective rent model is compared with the secondary grade asset face-rent model suggests that controlling for this bias is unlikely to change any conclusions in this study.

Of particular concern is an unobserved characteristic that determines effective rent prices and also affects whether the signing incentives necessary to calculate effective rent are observed. Table 6.8 presents correlation coefficients between the stochastic error terms in the estimation of Equation 5.6 and the estimation of the selection equation. For all five specifications of the effective rent model, there is no significant correlation between the error terms. This does not indicate that sampling bias has no effect on the results, but that any bias, such as secondary assets, is known and can be evaluated.

Table 6.8. Correlations between the residual error terms of Equation 5.6 and residuals from the selection model. Statistics are the correlation coefficient and its *t*-value.

Specification	$\rho_{\varepsilon u}$ (Error correlation between Equations 5.6 and 5.7)
1 (No Energy Variables)	-0.017 (-0.319)
2 (NABERS Categories)	-0.036 (-0.662)
3 (Precise NABERS Ratings)	-0.037 (-0.685)
4 (Energy Consumption)	-0.021 (-0.379)
5 (Consumption Quintiles)	-0.030 (-0.554)

6.2.2 Heckman Selection Model

The correlation test in Table 6.8 is a strong indication that adjustments to the effective rent model based on an unmeasured determinant of effective rent are unnecessary. To demonstrate this, this section presents the results of the jointly estimated Heckman selection model described at the end of Chapter 5. While the correlation coefficients in Table 6.8 are a good proxy for the relationship between the stochastic error terms in both equations, a joint estimation using maximum likelihood analysis provides a greater level of computational accuracy. Given the lack of a correlation, one would expect no change to the results of the effective rent model when a Heckman correction is applied to estimate the influence of the unknown sampling bias.

Table 6.9 presents the results for the coefficients of the effective rent selection equation when estimated with the model of effective rent determinants plus the inverse Mills Ratio to control for sample bias introduced as a result of any joint error distribution. Coefficients are nearly identical to those presented in the probit estimation of the selection equation (Table 6.7). The correlation between the errors of the two equations in the Heckman selection model, presented at the bottom of Table 6.9, has grown, but remains well beyond the levels normally associated with statistical significance away from a zero value.

A lack of correlation between the errors effectively means the coefficient for the Inverse Mills Ratio is zero, leaving the effective rent model unchanged from the specification in Equation 5.6. As expected, the estimation results of the effective rent model in the Heckman selection process (Tables 6.10a and 6.10b) are nearly identical to the original estimation of the effective rent model presented in Table 6.5.

Table 6.9. Estimations of coefficients for selection function specified in Equation 5.7. Dependent variable equals 1 if effective rent is observed, 0 otherwise. N=673. Statistics are coefficient (*t*-value). Estimated simultaneously with Equation 5.8 (Tables 6.10a and 6.10b) using maximum likelihood analysis.

Independent Variable	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**	**Spec. 5**
Asset Mgmt. Firm					
AMP	-0.275 (-0.806)	-0.249 (-0.735)	-0.244 (-0.72)	-0.269 (-0.787)	-0.263 (-0.777)
CBRE	0.488** (2.18)	0.493** (2.21)	0.497** (2.22)	0.488** (2.18)	0.485** (2.17)
Colliers International	0.084 (0.267)	0.079 (0.252)	0.072 (0.229)	0.080 (0.254)	0.082 (0.263)
DEXUS	-0.245 (-0.886)	-0.218 (-0.795)	-0.211 (-0.764)	-0.240 (-0.867)	-0.232 (-0.845)
Investa	1.011*** (4.90)	1.026*** (4.97)	1.026*** (4.97)	1.012*** (4.90)	1.021*** (4.93)
Jones Lang LaSalle	0.354** (2.12)	0.369** (2.21)	0.370** (2.22)	0.356** (2.14)	0.362** (2.17)
Knight Frank	-0.226 (-1.223)	-0.217 (-1.171)	-0.220 (-1.186)	-0.226 (-1.223)	-0.220 (-1.185)
Mirvac	0.665* (1.745)	0.648* (1.695)	0.646* (1.690)	0.664* (1.743)	0.654* (1.712)
Stockland	-0.569 (-1.577)	-0.565 (-1.573)	-0.567 (-1.576)	-0.570 (-1.582)	-0.574 (-1.591)
"Other"	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Tenant Credit Quality					
Institutional Tenant	-0.832*** (-5.477)	-0.828*** (-5.455)	-0.827*** (-5.443)	-0.831*** (-5.475)	-0.830*** (-5.463)
Bank Guarantee Required	Reference	Reference	Reference	Reference	Reference
Asset Service Quality					
Premium	-0.525*** (-2.748)	-0.530*** (-2.782)	-0.533*** (-2.793)	-0.526*** (-2.756)	-0.527*** (-2.767)
A-Grade	Reference	Reference	Reference	Reference	Reference
B-Grade	0.445*** (3.417)	0.449*** (3.446)	0.448*** (3.444)	0.445*** (3.421)	0.447*** (3.433)
C-Grade	0.600** (2.176)	0.614** (2.218)	0.617** (2.226)	0.602** (2.182)	0.608** (2.199)
Constant	-0.205 (-1.357)	-0.218 (-1.431)	-0.218 (-1.437)	-0.207 (-1.366)	-0.212 (-1.396)
$\boldsymbol{\rho_{\varepsilon u}}$	**-0.062 (-0.29)**	**-0.151 (-0.69)**	**-0.171 (-0.75)**	**-0.079 (-0.36)**	**-0.116 (-0.52)**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.10a. Estimations of coefficients for vector variables ***ENERGY*** and ***LEASE*** in Equation 5.8. Dependent variable is the natural logarithm of effective semi-gross rent per square metre. N=673 (with 340 censored observations). Statistics are coefficient (*t*-value). Estimated simultaneously with Equation 5.7 (Table 6.9) using maximum likelihood analysis. Results continue on Table 6.10b.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			-0.023 (-0.671)		
1			-0.059 (-1.395)		
1.5			-0.025 (-0.821)		
2			-0.001 (-0.021)		
2.5			Reference		
3			-0.019 (-0.765)		
3.5			-0.006 (-0.231)		
4			-0.061** (-2.18)		
4.5 or 5			-0.060 (-1.604)		
Poor (0, 1, or 1.5)		-0.029 (-1.408)			
Below Average (2 or 2.5)		Reference			
Above Average (3 or 3.5)		-0.014 (-0.793)			
Best Practice (4, 4.5 or 5)		-0.060*** (-2.638)			
Energy Consumption					
Energy Use Intensity (natural log)				0.013 (0.450)	
Top Consumption Quintile (least energy efficient)					Reference
2nd Consumption Quintile					0.045* (1.947)
3rd Consumption Quintile					0.031 (1.455)
4th Consumption Quintile					0.016 (0.67)
5th Consumption Quintile (most energy efficient)					-0.016 (-0.563)
Oper. Expense Liability					
Net Lease	0.134*** (8.121)	0.146*** (8.542)	0.145*** (7.475)	0.136*** (8.002)	0.140*** (8.275)
Semi-Gross Lease	Reference	Reference	Reference	Reference	Reference
Lease Term Length					
Short (4 years or less)	-0.065*** (-4.304)	-0.058*** (-3.809)	-0.057*** (-3.711)	-0.066*** (-4.325)	-0.060*** (-3.917)
Average (5 years)	Reference	Reference	Reference	Reference	Reference
Long (6 years or more)	0.028 (1.389)	0.035* (1.738)	0.036* (1.784)	0.028 (1.392)	0.031 (1.556)
Lowest Floor Leased	0.009*** (5.520)	0.008*** (5.049)	0.008*** (5.015)	0.008*** (5.488)	0.008*** (5.410)
Lowest Floor Leased Squared	$-1.3\text{x}10^{-5}$ (-0.474)	$-1.0\text{x}10^{-6}$ (-0.037)	$-1.0\text{x}10^{-6}$ (-0.037)	$-1.2\text{x}10^{-5}$ (-0.417)	$-1.1\text{x}10^{-5}$ (-0.408)
Leased Area (natural log)	-0.011 (-1.390)	-0.009 (-1.218)	-0.009 (-1.144)	-0.011 (-1.403)	-0.010 (-1.301)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table 6.10b. Continuation of Table 6.10a, featuring regressor groups ***LOC, AST, MKT*** and the constant.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.137*** (-5.800)	-0.131*** (-5.595)	-0.129*** (-5.373)	-0.137*** (-5.806)	-0.126*** (-5.300)
Western Corridor	-0.124*** (-7.890)	-0.103*** (-5.570)	-0.104*** (-5.082)	-0.120*** (-6.637)	-0.104*** (-5.358)
Southern	-0.291*** (-4.151)	-0.262*** (-3.712)	-0.265*** (-3.736)	-0.285*** (-4.004)	-0.253*** (-3.492)
Walking Distance to Train (natural log)	-0.005 (-0.428)	-0.007 (-0.675)	-0.008 (-0.724)	-0.005 (-0.464)	-0.004 (-0.435)
Asset Service Quality					
Premium	0.305*** (8.649)	0.304*** (8.713)	0.303*** (8.359)	0.304*** (8.552)	0.307*** (8.730)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.153*** (-8.291)	-0.144*** (-7.650)	-0.143*** (-7.242)	-0.153*** (-8.279)	-0.146*** (-7.688)
C-Grade	-0.420*** (-11.969)	-0.429*** (-12.134)	-0.426*** (-11.352)	-0.421*** (-11.975)	-0.423*** (-12.084)
Asset Vintage					
Heritage (>60 years old)	0.211*** (4.263)	0.187*** (3.724)	0.187*** (3.643)	0.212*** (4.271)	0.195*** (3.883)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	-0.024 (-1.19)	-0.019 (-0.95)	-0.016 (-0.79)	-0.024 (-1.18)	-0.023 (-1.18)
Commencement Half-Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	-0.015 (-0.40)	-0.022 (-0.58)	-0.028 (-0.73)	-0.014 (-0.36)	-0.028 (-0.73)
January to June 2008	0.153*** (4.224)	0.141*** (3.852)	0.134*** (3.528)	0.155*** (4.248)	0.137*** (3.699)
July to December 2008	0.236*** (6.032)	0.230*** (5.891)	0.221*** (5.475)	0.237*** (6.050)	0.223*** (5.694)
January to June 2009	0.175*** (4.381)	0.166*** (4.083)	0.160*** (3.848)	0.178*** (4.402)	0.158*** (3.886)
July to December 2009	0.038 (0.976)	0.034 (0.860)	0.028 (0.691)	0.040 (1.026)	0.027 (0.673)
January to June 2010	0.075** (2.143)	0.075** (2.077)	0.069* (1.873)	0.079** (2.190)	0.069* (1.922)
July to December 2010	0.098*** (2.900)	0.095*** (2.740)	0.088** (2.456)	0.101*** (2.933)	0.091*** (2.605)
January to June 2011	0.104*** (2.912)	0.107*** (2.967)	0.102*** (2.773)	0.106*** (2.946)	0.098*** (2.703)
July to December 2011	0.123** (2.348)	0.121** (2.300)	0.113** (2.117)	0.125** (2.374)	0.113** (2.132)
Constant	6.335*** (81.17)	6.355*** (81.67)	6.366*** (78.09)	6.247*** (79.94)	6.312*** (80.50)
Log-Likelihood	**-141.17**	**-137.37**	**-136.69**	**-141.07**	**-137.37**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

6.3 Conclusions and Discussion

The main conclusion of this study is the lack of a consistent relationship between asset energy efficiency and the price of office rents in central Sydney. Face rent models of the entire population of observations in the lease database found no systematic trend in the price of semi-gross face rent as a function of various measures of energy consumption. Adding the ***ENERGY*** vector to Equation 5.5 adds no useful information to the model of face rent. However, if the population is divided into prime and secondary asset submarkets, a very weak relationship between asset energy consumption and face rent emerges in Appendix 3: a negative relationship in the case of prime assets and a positive relationship in the case of secondary assets.

Taking all cash flows specified in a lease contract into account by calculating effective rent did not change the main conclusion. Energy efficiency premiums do not appear to be negotiated as an adjustment to the signing incentives offered in each lease contract. If anything, including incentives produces a weak positive relationship between asset energy consumption and effective rent. Tests and regression corrections for unmeasured sampling bias associated with the non-random selection of observations disclosing signing incentives demonstrate with high confidence that unmeasured sampling bias does not affect the results of the effective rent model. However, a known sampling bias towards secondary assets may be responsible for the weak positive relationship between asset energy consumption and effective rent.

Control factors representing other lease contract characteristics, asset characteristics, location and market cycle effects consistently explain over 85% of the variation in rent prices. In particular, tenancy floor level, asset service quality, submarket location, asset heritage, market conditions at the time of lease commencement and base-year operating expense liability are significant determinants of both face and effective rent prices. This consistency remains regardless of the data used to represent energy consumption.

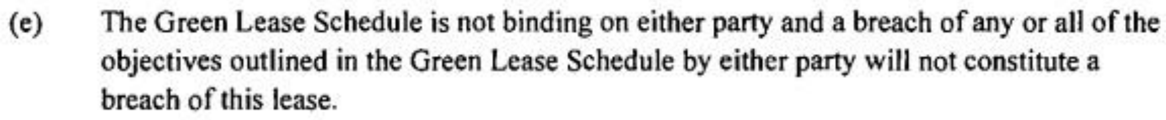
The remainder of this chapter considers the implications of these findings. First, the motivation to pay for asset energy efficiency is considered in the Sydney context, with a theory developed that financial and legal liabilities are too weak for a relationship between asset energy efficiency and rent prices to develop. Second, these findings diminish the importance of realigning incentives in order to pay for investment in asset energy efficiency. Although tenants do benefit from an owner's capital investment in energy efficiency, this benefit is trivial. Third, tenant indifference to operating expenses may be responsible for the curious net lease premium observed in this study. Finally, the effect of introducing mandatory energy performance disclosure in the office leasing market is discussed.

6.3.1 Tenant Motivation to Pay for Asset Energy Characteristics

Having failed to reject the null hypothesis of no relationship between rent and asset energy efficiency, three motivations from the tenant's viewpoint to pay a green rent premium – reducing factor costs, legal obligations, and social responsibility – are examined. In Sydney, the first two motivations are trivial. This suggests that social responsibility and other qualitative benefits are not strong enough to elicit rent premiums for the whole of the Sydney market.

Businesses rent office space as one of many factor costs in the output of office work. When these factor costs are examined in the case of Sydney, energy costs and progressive efforts at carbon pricing are trivial. In mid-2010, annual Sydney energy costs for commercial offices averaged A\$16.78 per m^2 of Net Lettable Area (NLA) and annual net rent costs averaged A\$542.31 per m^2 of NLA (Property Council of Australia, 2010). In early 2011, the annual cost of office labour in Sydney was approximately A\$4,700 per m^2 of NLA – nine times the cost of net rent and 280 times the cost of energy (Gabe and Gentry, 2013). Even a progressive carbon tax at A\$23 per tonne is trivial, adding an annual cost of approximately A\$3 per m^2 of NLA for an average Sydney office building. If energy cost savings are a motivation for tenants to pay more rent, a 3% semi-gross rent premium – the median from studies of Energy Star buildings in the United States (see Section 1.2.2) – would need to place the tenant in a zero-energy cost building in order for the tenant to be financially indifferent. While 4-star and above NABERS Energy rated buildings are energy efficient relative to market averages, they are far from zero energy consumption. Referencing Table 5.3, if tenants in buildings with below average NABERS Energy ratings shift to buildings with best practice ratings, they will save approximately 37% in energy costs, which translates into an approximate annual savings of A\$7 per m^2 in semi-gross rent. All else equal, if these tenants agree to pay the equivalent of an average semi-gross face rent (A\$687/m^2/year according to Table 5.3), a 1% rent premium for energy efficiency would shift the entire benefit of energy cost savings to the owner.

Second, Australia is a global leader in “green lease” clauses – behavioural and financial obligations to conserve natural resources and reduce environmental pollution written into lease agreements (Hinnells *et al.*, 2008). Influenced by the Energy Efficiency in Government Operations policy discussed in Chapter 2, large landlords in Sydney include a “Green Lease Schedule”, which describes tasks to be performed by the landlord and tenant in regard to environmental performance, including energy conservation. In theory, tenants facing green lease obligations may be willing to pay a premium for a limited supply of highly-rated office space because these buildings already have systems in place for high performance, making the fulfilment of any obligations less costly. However, in the course of this research, nearly all Green Lease Schedules signed in Sydney between 2007 and 2011 were “light green”, or not enforceable with penalties in the event of a breach. Figure 6.4 is an example of the clause that removes any legal liability from the Green Lease Schedule. As such, green lease clauses are aspirational in purpose and do not represent a legal obligation, so tenants are not likely to pay a rent premium for green office buildings because of a Green Lease Schedule.



(e) The Green Lease Schedule is not binding on either party and a breach of any or all of the objectives outlined in the Green Lease Schedule by either party will not constitute a breach of this lease.

Figure 6.4. Example of disclaimer attached to most Green Lease Schedules in the lease database.

This leaves corporate social responsibility (CSR) and other qualitative motivations as the only logical driver for tenants to pay energy efficiency rent premiums. Most existing literature on CSR in the office property market is written from an owner's perspective, typically citing strategy as the driver for owners to avoid capital obsolescence because of green trends in the industry (Pivo and McNamara, 2005, de Francesco and Levy, 2008, Newell, 2008, Bauer *et al.*, 2011). But this study falls into line with Miller and Buys (2008), who argue that tenants are awaiting clear signals on costs and benefits and see green building as a task for owners and developers. Hence the results show that tenants' willingness to pay for energy efficiency is noisy, with low confidence in the pricing effects of energy efficiency differentiation in the market.

If CSR is the main driver for tenants to pay for asset energy efficiency, the literature suggests that demand for CSR should be higher for affluent firms, which are most likely to be tenants in prime quality assets. In the canonical paper on the theory of CSR as it relates to corporate strategy, McWilliams and Siegel (2001) argue that CSR activities are "normal goods", which means that as income rises, demand for CSR also rises. Low-income tenants are expected to be more price-sensitive. The findings in Appendix 3 that prime asset tenants produce a weak signal of willingness to pay for energy efficiency fits the McWilliams and Siegel hypothesis well. Hence this study can conclude that tenant demand for asset energy efficiency in Sydney is most likely associated with factors that affect the demand for social responsibility.

6.3.2 Are Split Incentives a Barrier to Investment in Asset Energy Efficiency?

In Chapter 2, a unique financial vehicle, the Environmental Upgrade Agreement (EUA), was described as an answer to the "split incentive" problem cited as a major barrier to investment in existing asset energy efficiency. The split incentive problem refers to the fact that asset owners are financially responsible for all capital improvements while asset occupants benefit from the operational effects of any capital improvements, such as lower costs arising from energy efficiency. An EUA provides a loan to an asset owner for capital investment in energy efficiency.

This loan is repaid through a recurring statutory charge levied by the local government (Blundell, 2012). Since statutory charges are included in the bundle of outgoings paid by tenants[4], this shifts some[5] of the financial responsibility for the capital investment onto current and future tenants as a solution the split-incentive problem.

However, an implication of this research is that Sydney tenants are indifferent to the trivial benefits related to increasing asset energy efficiency. Hence, the split incentive problem may not be as big a barrier to improving the environmental performance of the built environment as is often assumed. As was argued above, the financial benefits accruing to Sydney tenants from capital investment in asset energy efficiency is not significant when placed into the context of factor costs and legal obligations. On the opposite side of the split incentive, the possibility that asset-scale variables such as occupancy rates contribute to asset-scale energy efficiency rent premiums means that owners are likely getting a return on their capital investment in the form of improved sales yields and lower vacancy costs. While this study does not investigate asset sales or vacancy rates, such an argument can be supported by inference if this study is placed into the context of Newell *et al.* (2011) and the numerous asset-scale studies in the United States that found rental income premiums from the owner's perspective (see Section 7.2). If tenants are not paying rent premiums for accommodation in energy efficient assets but owners are receiving rent premiums, then this latter observation must arise as a result of reduced vacancy or other ownership cost reductions.

Therefore, financial innovations designed to reduce the split incentive barrier may be an even better deal for owners than expected. In the case of an EUA, tenants are paying for a capital improvement that enriches the owner's asset value while providing them with a trivial benefit that this research shows they are not willing to pay for.

6.3.3 The Net Lease Premium – a Signal of Split Incentives?

If split incentives do not appear to be a strong barrier to capital investment in operational energy efficiency, could the net lease premium be a signal of split incentives favouring the owners of net lease assets? Another potential explanation for the surprising net lease premium (Section 6.1.2.2) is tenant indifference to operating expenses, which could enable owners of net lease contracts to

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[4] Tenants on a semi-gross lease are exposed to increases in operating expenses above the base rent year, so they are just as liable to the introduction of EUA charges as net lease tenants once the base rent year has passed.

[5] Just how much of the statutory charge can be passed on to tenants varies by local government. In theory, the tenant should only be liable for payments up to the value of the benefits it is receiving. Some councils with EUA legislation in place, such as the City of Melbourne, require permission from existing tenants and an agreement as to the value of tenant benefits before an EUA loan is approved.

expend minimal effort to manage common area expenses and externalise the inefficiency on the tenant.

A potential problem with this theory is that Sydney tenants are always exposed to operating expenses. Semi-gross contract structures assign liability for increases over the base year to tenants. However, semi-gross asset owners must go to the market with a fixed base-year operating cost estimate. Increases over their estimate in the base year are not paid by tenants, but rather by the owner effectively receiving a reduced net rent component of the semi-gross rent payment. After the base year, increases are paid by tenants, though the reduced net rent component remains. In the case of net leases, increases over the base year estimate are paid by tenants at the end of the first rent year. This situation provides a natural incentive for semi-gross lease owners to manage operating expenses, particularly in years when they have vacancies, to increase rent yields. Hence the incentive to manage operating expenses in Sydney office assets is affected by lease contract structure.

A natural solution to the split incentive problem would be the mandatory use of semi-gross rent contracts. However, it is also possible that tenants in net lease assets value the inefficient spending on operational services, hence the rent premium. Owners with an incentive to manage operating expenses may find that reducing the quality and scope of services is necessary to stay competitive. On-going research into the net lease premium will explore this curious finding in more depth, but the attention of this study must return to the effects of asset energy consumption on rent paid by tenants.

6.3.4 The Effect of Mandatory Energy Performance Disclosure on the Leasing Market

This study potentially improves the understanding of market effects associated with the introduction of mandatory performance disclosure policies in regard to energy consumption and greenhouse gas emissions. There is no evidence that tenants change behaviours in response to the introduction of energy disclosure, despite evidence that the introduction of NABERS Energy in Australia led to significant investment and improvement in building operational efficiency (Chapters 3 and 4). However, some caution is advised in applying the findings of this study to mandatory disclosure because all leases in the Sydney lease database were signed prior to the official enforcement of the Australian Building Energy Efficiency Disclosure (BEED) Act discussed in Chapters 3 and 4.

In particular, the context of the office market may be an important indicator of the effect of disclosure policies. For example, Sedlacek and Maier (2012) found that green building councils in

Europe are inadvertently taking on the role of governing asset quality standards. In Sydney and across all of Australia, the Property Council of Australia has defined asset quality standards well before the introduction of NABERS and mandatory disclosure policies. Hence a more general theory of the effect of mandatory energy rating disclosures on the property market would suggest it is a function of the availability of quality ratings. If the scope of quality ratings are non-existent (i.e. Europe) or perhaps incompletely segmented, then the introduction of energy ratings provides consumers with a method to differentiate at least one aspect of asset quality (multiple aspects in the case of new asset green building ratings discussed by Sedlacek and Maier). On the other hand, quality ratings in Australia are some of the most well-defined in the world; hence the introduction of mandatory NABERS Energy disclosure has had little effect on the differentiation of the Sydney market.

The exception to the lack of an effect from energy disclosure on the Sydney leasing market may be the weak signal that prime asset tenants adjust their rent bids based on asset energy consumption. This observation may be related to the desire of the Sydney market to further differentiate prime asset quality beyond the division of Premium- and A-Grade. For example, an energy-efficient A-grade asset may be seen as an A plus-grade asset. Meanwhile, the secondary market is seeking value for money in regards to the services provided. As was argued in Section 6.1.1.2, energy consumption is likely to be negatively associated with partial A-grade service provision; hence this market interprets energy efficiency with a discount effect.

6.4 Next Steps

Having concluded in this chapter that, as a general proposition, tenants are unwilling to pay for energy efficiency in office accommodation, there is an interesting puzzle that emerges when this conclusion is addressed in parallel to the conclusion of Chapter 4, which found increased owner investment in energy efficiency once NABERS ratings were introduced. Chapter 7 will discuss the apparent paradox that arises from combining the conclusions from all research questions in this study. Why do owners invest in energy efficiency when tenants are not willing to pay for the benefits?

From the results of this study, a number of further research questions have been identified. The surprising presence of a net lease structure premium is the most obvious line of enquiry, with potential hypotheses discussed that include the role of professional lease valuation practices; the potential for net leases to be an instrument for unidentified differences in asset quality; and the possibility that owners are able to externalise of costs that are trivial from a tenant perspective.

In regard to research on energy efficiency rent premiums, further studies will need to look at the potential for expectations of future energy efficiency performance to be associated with face rents. This study used the audited rating at the time of lease but as more NABERS Energy data becomes available, assets will begin to reach their post-NABERS performance equilibriums. Using future certifications could answer whether tenants pay energy efficiency rent premiums in anticipation of future performance instead of basing their rent decisions on existing performance. A challenge with this line of enquiry is disassociation of energy upgrades from general amenity upgrades; Kok *et al.* (2012b) found that both tend to occur in the same capital investment in the United States.

Chapter 7
Conclusions

To conclude, this chapter first revisits the four major research contributions made in this thesis, summarising the findings that fill the research gaps identified in Chapter 1. Section 7.2 then discusses the apparent logical enigma associated with the finding that owners are willing to invest capital in asset energy efficiency despite tenants being unwilling to pay its operational benefits. Section 7.3 summarises the implications for industry and policymakers before Section 7.4 summarises the limitations of the research in this study. Section 7.5 concludes the thesis with an outlook of new research directions resulting from this study.

7.1 Summary of Research Findings and Contributions

A series of quantitative models in Chapter 4 found a strong and consistently positive relationship between depth of NABERS energy participation and operational energy efficiency. After participating in six NABERS Energy audits over a period of approximately six years following an asset's initial audit, empirical evidence of a post-certification energy consumption equilibrium of approximately 430 MJ/m^2/year emerges in Australia. It was calculated that this post-certification equilibrium represents a rough 25% reduction in consumption relative to the pre-certification equilibrium, matching estimates made by Pacala and Socolow (2004) regarding the expected effect of introducing modern technologies into existing buildings. Year of entry into NABERS Energy does not appear to influence this post-certification equilibrium, though it was noted that periods of raised interest in energy management delivered faster transitions toward this equilibrium. These findings are an important contribution to the research gap identified in Section 1.1.3 associated with the lack of knowledge regarding repetitive certification as a market differentiation technique to promote asset energy efficiency.

The other research gap associated with environmental performance, identified in Section 1.1.4, concerns the motivation for an asset owner to engage with NABERS Energy certification. The fixed depth of participation models estimated in Chapter 4 make some early contributions to understanding differences in energy performance outcomes between voluntary and mandatory adopters of NABERS Energy. At the time of the third certificate, there is no statistical difference in the energy savings of a voluntary adopter and the energy savings of a mandatory adopter of NABERS Energy. More liberal definitions of a mandatory adopter show that this relationship is likely to hold true at the end of an asset's fourth certification period, though these research findings come with the caveat that they are being measured in the middle of a transition to post-certification equilibrium, so future results may differ. The early evidence presented here suggests that mandatory disclosure policies mooted as a potential solution to mitigate energy-related greenhouse gas emissions from existing property asset stocks are likely to be effective at speeding up a much slower market transformation reliant on voluntary adopters and spillover effects to non-participants.

Chapters 5 and 6 changed the focus of the research to the market effects of repetitive energy certification on tenant willingness to pay rent as a function of asset energy consumption. While this is a crowded research space, Section 1.2.3 argued that existing research into the market effects of energy efficiency is limited by its choice of the asset-scale to measure rental income, its use of uncertified assets as a no-intervention benchmark, and omitted variables when tenancy scales are examined. In this thesis, the comprehensive data gathering approach of extracting lease transaction data directly from a sample of lease contracts in Sydney, a market where energy rating was both comprehensive and not truncated, produces a third contribution to the property literature. Using this dataset to estimate a number of econometric models and statistical tests results in the conclusion that tenants do not consistently alter their office rent bids as a function of energy ratings or raw energy consumption measured prior to the lease agreement (see Table 7.x). The same model run on a number of subsamples of the dataset in Appendix 3 found that wealthy tenants demonstrate a weak preference to pay for energy efficiency, in line with theoretical models that suggest environmental quality is a luxury good (McWilliams and Siegel, 2001, Fuerst *et al.*, forthcoming).

Table 7.1. Summary of the coefficients of energy consumption variable effects on Sydney office rents. For brevity, Specification 2 represents the effect of NABERS Energy ratings and Specification 4 represents the intrinsic value of energy use intensity (EUI) as a continuous variable. Full model specification references provided in brackets.

	Specification 2 – NABERS Energy Ratings				**Spec. 4**
Dependent Variable	**Poor (0, 1, 1.5)**	**Below Avg. (2 or 2.5)**	**Above Avg. (3 or 3.5)**	**Best Prac. (4 and up)**	**EUI** (MJ/m^2/yr.)
Semi-Gross Face Rent (PCA Submarkets; Table 6.1)	-0.011	*Reference*	0.021**	-0.014	0.002
Semi-Gross Face Rent (Small Submarkets; Table 6.1)	-0.009	*Reference*	0.022**	-0.017	0.005
Effective Semi-Gross Rent (Table 6.5)	-0.030	*Reference*	-0.014	-0.059**	0.012
Effective Semi-Gross Rent (Heckman Select.; Table 6.10)	-0.029	*Reference*	-0.014	-0.060**	0.013

** indicates statistical significance at the 95% level.

The fourth major contribution to the study of real estate from this thesis is the development of a theory as to why tenants would not elect to pay for asset energy efficiency. As Section 1.2.1 noted, the existing literature is full of advocacy-related arguments stating that asset energy efficiency should lead to greater rent bids (Sayce *et al.*, 2010). The counter-argument is explored in Section 6.3.1 by analysing the role that energy consumption has as a factor of production in office work. Financial motivations from the tenant viewpoint are weak; in Sydney, energy consumption accounts for just over 1% of accommodation costs, *excluding* labour, which is nearly ten times the cost of accommodation. Legal obligations could create non-financial incentives, but despite leadership in Green Leases, this study found Sydney office owners prefer “light-green” leases, which is the equivalent of a memorandum of understanding without penalties for non-compliance. This leaves qualitative benefits such as corporate social responsibility positioning as the drivers for tenants to pay for energy efficiency and other green building attributes. The theory developed in Section 6.3.1 is well-supported by the results of this study, particularly the finding that only wealthy tenants appear interested in energy efficiency, and qualitative surveys of tenants in the literature with inconsistent findings regarding the demand for energy efficiency (Miller *et al.*, 2008, Miller and Buys, 2008).

In the course of pursuing these research outcomes, this thesis also makes a number of minor contributions to the property literature. The first minor contribution is a new modelling approach; the models related to the environmental effectiveness of NABERS Energy specified in Chapter 3 and estimated in Chapter 4 are the first attempts at modelling energy improvements in commercial property over time. Second, the detailed process described for extracting transaction data from original lease contracts in Chapter 5 is likely to be useful for greater collaboration between the property industry and academic scholars interested in detailed valuation and market analysis techniques at the tenancy scale. The third minor contribution comes from the trial of smaller submarket delineations in the Sydney office market. This study found that while smaller submarkets presented a better picture of the relative position of intra-submarket location effects on rents, the increase in explanatory power in the hedonic price model over the Property Council of Australia-specified submarkets was minimal, while spatial autocorrelation between other control variables – including energy efficiency – increased. Lastly, this thesis found that the purchase of greenhouse gas emission offsets via the Green Power programme is a complementary activity to operational greenhouse gas mitigation, not a substitute.

7.2 The Energy Efficiency Investment Enigma

Combining the four main contributions from this study together raises an interesting question: if tenants are unwilling to pay for asset energy efficiency in Sydney, why are owners investing? To answer this question, an analysis of factors affecting value at the asset scale – vacancy rates and cap rates, for example – is necessary. This study did not examine asset-scale data from the owner's point of view, so any insight into this enigma must include the earlier study of the relationship between energy efficiency and property prices in Australia by Newell *et al.* (2011), who investigated asset-scale data from some of the same office assets in the Sydney central business district [CBD]. However, the rent results from the tenancy scale in this thesis and rent results at the asset scale in the Newell study are not directly comparable because the reference chosen to represent a value benchmark in the Newell study, uncertified assets, is different than the use of a median NABERS Energy rating as a benchmark in this thesis[1]. Another insight into asset-scale data in the Sydney CBD is provided by the Investment Property Databank [IPD] Green Index, which presents aggregated descriptive statistics of asset-scale investment return data based on data provided by IPD members (IPD, 2014).

These asset-scale studies integrate well with the research in this thesis because they argue that much of the green value premium in Australia can be attributed to capital value enhancement. The IPD Green Index data is most revealing because it analyses capital return and income return on investment separately by star rating thresholds. For the Sydney CBD market, there is little discernible difference in income return as a function of NABERS Energy rating (IPD, 2014). Instead, IPD shows that variation in capital value is responsible for differentiating investment return as a function of energy efficiency. The Sydney CBD results from Newell *et al.* (2011), which are presented in Table 7.2, tell a story that minor improvements in rent/vacancy[2], cap rates and outgoings each contribute to a wide spread in estimated capital value as a function of NABERS Energy rating categories.

Table 7.2. Results of Sydney CBD asset-scale value premiums as a function of NABERS Energy rating relative to a benchmark sample of uncertified assets. Source: Newell *et al.* (2011).

Value Attribute	2.5 Stars and Below	3 Stars and Above
Gross Rent	-3.9%	-1.9%
Vacancy Rate	1.4%	-0.2%
Signing Incentives	3.1%	3.1%
Yield Rate (Cap Rate)	0.1%	0.0%
Outgoings (Operating Expenses)	0.3%	-3.4%
Capital Valuation Proxy	**-8.4%**	**0.3%**

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[1] As one can see in Table 7.2, the asset-scale rent results from the Newell study could be interpreted by suggesting the pursuit of any level of NABERS Energy certification reduces rental income receipts. Because they are difficult to interpret in the context of energy performance (see Section 1.2.3 for more), uncertified assets are excluded from study in this dissertation. Hence the tenancy scale outcomes from this dissertation cannot be directly compared with the asset scale outcomes from the Newell study.

[2] Newell *et al.* use average gross rent per square metre to represent rent. Whether an adjustment for vacant space is included in their rent calculation is unclear. The relative increase between the two NABERS Energy categories is almost identical for the gross rent and vacancy variables, leaving the possibility open that the cause of both increases is the same, much like the observation regarding the Eichholtz *et al.* (2010) study discussed in Section 1.2.3.

Strong empirical evidence from this study combined with the IPD Green Index at the asset scale results in a narrative that owners do not invest in energy efficiency to increase rental income per tenant. Findings from Newell *et al.* (2011) show that, relative to a group of uncertified assets, obtaining certification for energy efficient assets (3 stars and above) is associated with reduced vacancy rates, operating expense liabilities and reduced cap rates, all of which influence capital return. One conclusion supported by all three studies is that owners invest in asset energy efficiency not because tenants will pay more, but because their investment is capitalised.

Hence, in line with Newell (2008) and de Francesco and Levy (2008), this study concludes that private investment in asset energy efficiency best fits the theory of an asset positioning strategy, not an income generation strategy. The energy efficiency investment enigma described above is a product of expectations from green building advocates that energy efficiency is associated with tenant willingness to pay for energy efficiency. This expectation appears to have little empirical support in the data. Section 6.3.1, which provided the "tenant indifference" framework as to why energy cost savings are trivial from the tenant point of view, appears to be a theory better supported by the empirical evidence at both the tenancy and asset scales[3]. Further support to the theory that private investment in energy efficiency is an asset positioning strategy is provided in the literature by Kok *et al.* (2012b), who surveyed investors in energy efficiency retrofits in the United States and found that energy efficiency upgrades are typically integrated with a larger investment in the asset that includes fit-out upgrades and other modernisation improvements.

7.3 Implications for Public Policy and Property Practice

The multiple findings of this research discussed above have implications for market-based policy interventions in the property sector as well as for industry practice. This section discusses five applications of the research in this study. First, results from the fixed-certificate models in Section 4.1.4 permit the preliminary construction of a framework for successful market-based policy that aims to reduce energy-based greenhouse gas emissions from the property sector. Second, the findings of tenant indifference to asset energy efficiency in Sydney imply that split incentives are not as significant of a barrier to private investment in asset energy efficiency as the literature assumes. The third implication, described in the section above, is that private

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[3] Support of the tenant indifference theory in Section 6.3.1 is based on data from Sydney only, though the IPD Green Index suggests capital return is more important than income return in all major Australian markets. One bias that may affect the application of this conclusion outside of Australia is the relative homogeneity of lease contract structures in Sydney. Tenants are liable for increases in energy costs in both net and semi-gross contract structures. Thus, owners will not benefit from energy cost savings other than indirectly via the offer of a more competitive total gross rent.

investment in energy efficiency upgrades is most likely to benefit property owners with a need to reposition assets in a market. Fourth, property investors looking to profit solely from an energy upgrade investment are likely to wait until capital returns are realised, which increases risk. Finally, Australian property occupiers can learn from this research to trust their traditional market rent valuation methods as NABERS Energy ratings do not appear to be a determinant of rental rates. The following subsections explain each implication in more detail.

7.3.1 A Framework for Successful Market-Based Policy

One of the outcomes of this research is evidence of a successful strategy towards meeting 50-year greenhouse gas mitigation targets for the property sector in approximately six years (see Section 4.2.1). The role that market differentiation plays in providing incentives for energy-based greenhouse gas emissions implies a framework for policy success in Australia that may be useful to other governments interested in mitigating greenhouse gas emissions from energy demand in the built environment. The fixed-certificate models in Section 4.1.4 that found later adopters just as effective as early adopters at reducing asset energy consumption, if not faster, suggest that this link between participation and measured outcome requires three steps. First, a segment of the local industry sees value in adopting a voluntary approach to energy performance differentiation. Second, pioneer investments in energy efficiency then create a market for retrofits, testing cutting edge technologies and management strategies. With the establishment of institutional knowledge in energy efficiency retrofits, the third step, transition to a mandatory disclosure environment, is possible because costs and benefits are understood. Such a transition ensures that asset owners expect future audits, which were shown in Section 4.1.3 to be an important factor in asset energy efficiency investment. Section 4.2.4 discusses this framework in more depth.

However, this framework is only preliminary. There are other potentially important contributions to greenhouse gas mitigation outcomes in Australia besides the motivation to participate in NABERS Energy that were not thoroughly tested in this study. Unique characteristics of the NABERS Energy assessment and Australian property markets likely contribute to observed greenhouse gas mitigation success. For example, unlike most green building assessment systems, NABERS Energy is a performance rating system that has a non-truncated distribution of performance thresholds; most overseas assessments are asset ratings only interested in identifying market leaders, making it impossible to differentiate the vast majority of assets in those markets. Perhaps, as Chatterji and Toffel (2010) implies, existing asset owners are better motivated by the avoidance of negative publicity associated with poor performance more than they are motivated by competition for leadership. In addition, performance ratings have the ability to influence both human and design factors involved in the production of greenhouse gas emissions, better aligning incentives between designers and users.

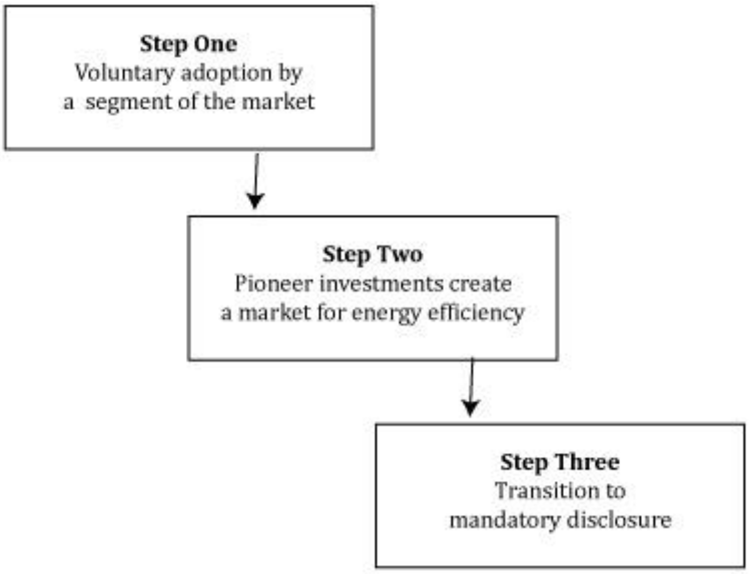

Figure 7.1. Preliminary framework for successful greenhouse gas mitigation activities in Australia.

Another context to consider within the framework is the scope of complementary policy actions in Australia besides asset differentiation via mandatory disclosure, notably the AusIndustry Green Building Fund that likely helped create the market for existing asset retrofits (see Section 2.2.2). Hence some intervention may be needed in regard to the second step of creating market for retrofits. Future research that explores the effect of the AusIndustry Green Building Fund on greenhouse gas mitigation in Australia is planned.

7.3.2 Split Incentives

The second major implication of the findings in this thesis concerns the role that traditional split incentives – when owners fund capital improvements for the operational benefit of tenants – play in regard to energy efficiency investments. The evidence in this thesis supporting a theory of tenant indifference towards operational energy benefits, along with the existing literature on asset-scale capitalisation of energy efficiency investments discussed above, imply that split incentives are not a significant barrier to capital investment in greenhouse gas mitigation. This runs counter to untested theories in the literature that assume split incentives are a major barrier to investment (Galuppo and Tu, 2010, David Gardiner & Associates, 2010, Kok *et al.*, 2012b).

A potential further implication is that instruments designed to eliminate this traditional understanding of split incentives may create a market failure that enriches owners at their tenants' expense, another "split incentive" scenario, but with traditional roles reversed. Energy Upgrade Agreements [EUA] and equivalent financing vehicles attempt to fix the traditional split incentive by allocating repayment liabilities for a loan on existing and future tenants. As an extreme example, an owner could invest in asset energy efficiency using an EUA, then immediately sell the asset and collect the capital gain while the burden of repayment of the loan rests with the existing tenants. Of course, an efficient market should self-police this extreme example; prospective asset buyers would demand a higher income yield (cap rate) in exchange for increased risk associated with finding future tenants that will be liable for a share of the loan repayment on top of traditional operating expenses. That process would lower the capital value and any expected capital return. But the surprising net lease premium, where tenants in lease contracts appear willing to pay approximately 9% higher semi-gross equivalent rent, all else being equal (Section 6.3.3), suggests tenants may also be indifferent to these repayment obligations, particularly if they are in a city that restricts tenant repayment penalties to the expected value of energy savings. Given that tenant indifference to energy costs can be placed in a framework of rational expectations (Section 6.3.1), it seems most logical that private capital investment in asset energy efficiency is best rewarded in the normal way via enhanced capital value, as opposed to leveraging that tenant indifference as an economic externality.

As a final note on split incentives, reviewers of papers arising from this study have found the conclusion of tenant indifference to energy costs surprising, especially given how the literature often states that energy is the "most manageable cost" in the context of asset management. For example, Eichholtz *et al.* (2013) notes that up to 30% of operating costs in a typical office asset in the United States is energy costs. But, of course, this is from the asset manager's viewpoint, where a much smaller labour cost is spread over an entire asset and rental payments are income, not factor costs. For tenants, labour costs and rental payments conspire to marginalise operational energy costs. Thus, instead of an EUA and other financing vehicles, a more natural means of eliminating the traditional split incentive exists: the full-service gross lease, which transfers all operational energy cost liabilities on to the owner. Section 6.3.3 argued that one potential source of the net lease premium is inefficient management of operating expenses in assets employing net leases. Given the risk of creating a reverse split incentive with an EUA or similar financing vehicle, it would appear that a transition to full-service gross leases – which are very rarely used in Sydney – would be a better approach in any market where the traditional split incentive is shown to be a barrier to investment in operational efficiency[4].

7.3.3 Asset positioning strategy

The third implication of the research in this study is how property owners can identify assets most likely to benefit from investment in asset energy efficiency. As Section 7.2 argued in greater depth, this study, combined with existing literature, suggests that private investment in asset energy efficiency is most profitable when there is an opportunity to enhance or sustain capital value, not as an income generation strategy.

For example, in central Sydney, the most energy inefficient assets are Premium-grade assets currently located in the prime "City Core" submarket (see Figure 3.2 and Table 5.4). These assets currently have strong market positioning and thus see little income enhancement value in energy efficiency investment. However, looking forward, a major redevelopment is occurring in the waterfront Walsh Bay submarket (see Figure 3.2), which will see nearly 300,000 m^2 of prime office space enter the market (Colliers International Research, 2012). Agencies such as Colliers International also report a number of prime tenants have announced they will leave the City Core for the Walsh Bay development. For the current owners of City Core properties, repositioning using investments in asset energy efficiency is likely to be a useful strategy to sustain capital value and attract new tenants.

Does this also mean energy efficiency will be most profitable for secondary assets? A limitation of this asset positioning implication is the fuzzy interaction between repositioning an asset to improve is service quality and repositioning via asset energy efficiency. Such distinction is difficult to ascertain in secondary assets. As Kok *et al.* (2012b) found, investment in modernisation, service quality, and energy efficiency are typically simultaneous. In Premium and A-grade assets, the investment is tilted towards the energy efficiency outcome because there is little else the asset must do to differentiate itself in regard to service quality (see Table 2.2), while B- and C-grade asset owners are faced with an additional investment opportunity in partial A-grade service provision. Prime tenants may not pay much more for energy efficiency, all else being equal, but they may choose an energy efficient tenancy over another, in line with the hypothesis that asset energy efficiency influences vacancy rates as opposed to rental income. Hence asset repositioning via energy efficiency investment appears to be most profitable for

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[4] It could be that the choice of Sydney for a case study biases the results because the Sydney market features the highest labour and rent costs across all Australian office markets. Smaller markets may find that energy cost is less marginalised from the tenant viewpoint, though asset owners are always going to face stronger incentives in a gross lease arrangement than tenants will face in a net lease arrangement, all else equal.

prime asset owners. It is less clear how asset energy efficiency investment affects secondary asset values relative to equivalent investments that provide partial A-grade service qualities; the models in Appendix 3 suggest secondary tenants value energy efficiency less than prime tenants, in line with corporate social responsibility theories (McWilliams and Siegel, 2001) and an interpretation that energy consumption proxies partial A-grade service provision.

7.3.4 Investment in Energy Upgrades

In the event that asset positioning is not a possible investment strategy, the results of this study give further insight into another potential investment strategy of acquiring an energy *inefficient* asset for the purposes of increasing NABERS Energy ratings to add value. In this strategy, an investor acquires a low-NABERS Energy rated asset and upgrades its rating, holding all else equal. Could this be a profitable strategy?

The research in this thesis did not consider such a question directly, but a hypothesis can be developed via the contributions of the study integrated with existing literature into the relationship between property values and energy efficiency (See Section 1.2). Of most relevance is Newell *et al.* (2011), who found asset-scale measures of investment worth in Sydney, such as appraised value, are greater in assets with high NABERS Energy ratings relative to uncertified assets. This thesis found that rental rates do not increase as a function of NABERS Energy ratings.

Together, this leads to an implied hypothesis that asset energy efficiency is valued at the asset scale (*e.g.* increased occupancy, reduced cap rates or increased asset value), so capital value appreciation, not increased income, is the likely profit mechanism. Such a hypothesis helps integrate the two paths of this thesis, providing a logical narrative as to why owners appear to be investing in energy efficiency as an outcome of repetitive auditing (Chapter 4) despite evidence that tenants are not paying increased rental rates (Chapter 6).

Further research is needed to explain the relationship between asset value and energy efficiency to answer the question of profitability. Unless increased occupancy rates fully explain increased asset value – which is not the case with the Newell *et al.* (2011) observations[5] – it is likely that investors following this hypothetical energy upgrade investment strategy must wait until divestment of the asset to other investors in order to profit from the strategy. In this scenario, there is not only risk that capital must be invested well before profit is realised, but additional risk from the potential for future investors to lose interest in asset energy efficiency once it is

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[5] Newell *et al.* (2011) finds vacancy rate increases in all certified assets, including those with below average 2-star ratings. There was only weak evidence that vacancy rates decreased with increasing NABERS Energy ratings.

known that tenant demand is not strong enough to increase rental rates. This loss of interest would reduce demand from future investors and thereby reduce the potential profitability of the energy upgrade investment strategy.

7.3.5 Occupiers and Energy Efficiency

The fifth practical implication of this research is the general continuation of the *status quo* among occupiers of office property in Sydney. Rental rates, in general, are not a function of NABERS Energy ratings in a competitive market, thus occupiers and their valuation consultants can use traditional market rent valuation methods when negotiating market rent reviews. Note that this finding is based on data from the Sydney central business district only and may be limited to this competitive market (as described in Section 2.3.2).An interesting follow-up study would be to better understand the reason why there is insufficient demand from occupiers for energy efficiency. This study provided an initial theoretical proposal (Section 6.3.1) that argues tenants do not face sufficient financial and legal mechanisms to motivate their participation on those grounds. This leaves corporate social responsibility (CSR) and other more qualitative benefits as what could potentially motivate occupiers to pay a premium for energy efficient office space.

One hypothesis as to why these CSR benefits are not strong enough to affect market rental rates in Sydney is that occupiers may be electing to participate in corporate social responsibility efforts through their core businesses as opposed to their factors of production. For example financial services firms may participate in programmes designed to produce corporate social responsibility in financial services products, such as responsible financial management practices. CSR via tenancy procurement may not be as visible for occupier firms as CSR initiatives associated with their core business.

7.4 Limitations of this Study

Despite a great deal of attention to robust model specifications and data accuracy, limitations with econometric data are unavoidable. This is particularly true when new models are constructed in the absence of prior literature, such as those developed in Chapter 3 to test the effect of NABERS Energy participation on asset energy efficiency.

Section 4.2.3 discussed two potential limitations of these attempts to explain the relationship between the depth of participation in NABERS Energy and asset energy efficiency. The main concern was whether participation in NABERS Energy allowed the market to measure investment in operational energy efficiency caused by something else. Section 4.2.3.1 argued that based on the model construction and results, the following alternative explanations for “something else” could be rejected: spillover effects, energy cost inflation, a corporate social responsibility “arms race”, state policy variations, and the growth in office vacancy rates. What remains exogenous to the model explaining the role of NABERS Energy participation in asset energy efficiency are concurrent federal policies, such as the AusIndustry Green Building Fund or rating floors for government agency accommodation (see Section 2.2). Future research will aim to include additional tests, such as a difference-in-differences model around a particular policy to test these effects relative to the NABERS Energy effect model developed in this study.

All the econometric models in this study, including the more common hedonic price models specified in Chapter 5, need to be interpreted in the context of trends and events occurring simultaneously. A notable event that took place during this study was the global financial crisis of 2008. While Australia did not suffer large property market crashes like other capital intensive economies, there was a brief decline in investment returns from Australian office markets (see Section 2.3.1). However, it was shown that market variations in Sydney were well controlled for using binary time variables (see Section 6.1.5). Recent Sydney office market cycles have lasted approximately 8-10 years (Figure 2.8), so a four-and-a-half year window into rental transaction data cannot ascertain what effect the financial crisis (or other economic cycles) had on this study. However, one of the econometric studies on green asset value in the United States (Reichardt *et al.* 2012) attempts to map the effect of economic cycles on green asset value premiums, finding only a minor decline resulting from the global financial crisis, which affected the United States much more than Australia. Owing to the large number of variables that affect market rental prices in Sydney, this study does not have a sufficient number of transactions in each half-year to perform a similar investigation of whether an energy efficiency price premium is a function of time.

Another limitation of this study is sampling bias, which is common in research on certification because the observed population is often self-selected and not fully random. Section 4.3.2 argued that this study makes a significant improvement in this area relative to prior econometric studies. It was also identified that the analysis in this study covers primarily large office markets. However, there is nothing to suggest that lowering the size threshold for mandatory disclosure would produce alternate results; the variable for building or tenancy size was insignificant, both as a descriptor of energy savings and as a factor in rental price per square metre, in all models.

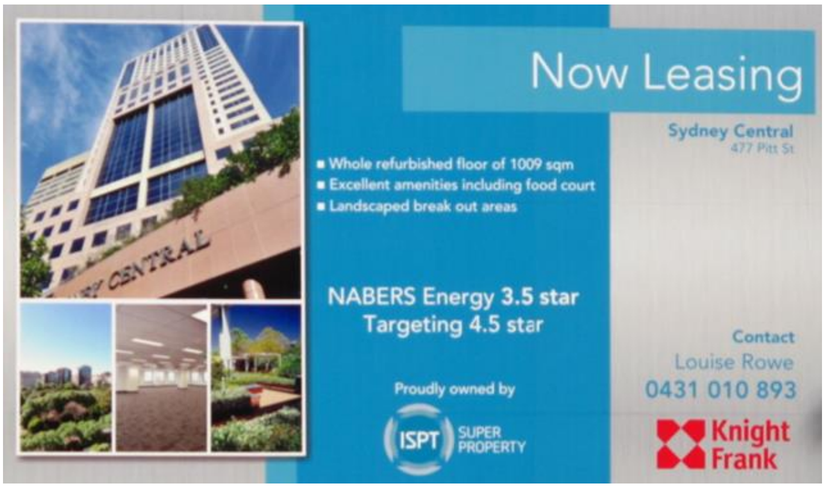
Statistical techniques to account for bias, such as a two-stage Heckman procedure (see Chapter 5 for a full description) were performed in the hedonic rental price model in order to control for potential bias. This had no effect on the relationships in the model, further supporting the quality of the data and sampling procedure adopted in this study.

7.5 Future Research Directions

The findings and limitations of this study produce a number of additional questions worthy of future research. Five of these will be discussed here. First, the curious finding regarding a semi-gross rent premium paid by tenants in a net lease structure is an apparent market failure that needs further investigation. The second future research opportunity involves the testing of a framework of tenant willingness to pay rent based on expectations regarding asset energy efficiency as opposed to the audit at the time a lease was agreed. In regard to the apparent success of greenhouse gas mitigation for participants in NABERS Energy, a third further research project will consider other explanatory variables, particularly the effect of over A$100 million in federal and state grant money awarded to develop the market for energy efficiency retrofits. Fourth, revisiting the comparison of environmental effects between mandatory and voluntary adoption of NABERS Energy over the next five years is important to ascertain post-mandatory disclosure equilibrium for the latter group and a possible shift in the post-certification equilibrium observed in the former. Finally, this study has only considered Australian markets; future comparative studies using similar methodologies for comparing environmental effects and lease market effects will be useful to ascertain the transferability of these findings.

The surprising net lease premium was discussed in Sections 6.1.2.2 and 6.3.3. Future research will be needed to explore why Sydney tenants pay higher semi-gross-equivalent rent in a net lease structure than they would in a semi-gross lease structure, all else being equal. Two speculative causes were put forward, including the role of standard valuation practices in segmenting net and semi-gross assets into separate markets as well as the possibility that there is an unmeasured aspect of asset quality that is specific to net lease assets. In addition, the theory regarding tenant indifference to operating costs in Sydney presents the possibility that net lease asset owners are able to externalise the costs of inefficient operating expense management practices.

A second research opportunity arises from the decision in this study to measure asset energy efficiency based on the most recent audit prior to the date of lease. As Figure 7.2 demonstrates, some asset owners in Sydney disclose current and target ratings to prospective tenants. This study found no consistent association between NABERS Energy star ratings at the time of lease and various measures of rent. Future research can explore whether there is a relationship between expectations of energy consumption and measures of rent.



Now Leasing

Sydney Central
477 Pitt St

- Whole refurbished floor of 1009 sqm
- Excellent amenities including food court
- Landscaped break out areas

NABERS Energy 3.5 star
Targeting 4.5 star

Proudly owned by
ISPT SUPER PROPERTY

Contact
Louise Rowe
0431 010 893

Knight Frank

Figure 7.2. Sydney lease advertisement displaying current and expected future NABERS Energy ratings.

The third opportunity for future research is to improve the explanatory power of the models attempting to explain the relationship between depth of NABERS Energy participation and measured energy savings. Section 4.1.3 argued that asset energy consumption is stochastic and the explanatory power of the models in this study is in-line with other studies attempting to model investment in asset energy efficiency (Kok *et al.*, 2012a, Fuerst *et al.*, forthcoming). But the discussion in Section 7.3.1 above argued that future models of the Australian market will attempt to incorporate the A$100 million of public funds that complemented the introduction of NABERS Energy over the time period in this study. Inclusion of these grants into the model may improve the explanatory power of the asset energy efficiency investment models.

The fourth research opportunity stems from a potential limitation of this study in comparing energy consumption outcomes between voluntary and mandatory adopters of NABERS Energy. Active enforcement of mandatory disclosure only commenced three years prior to this study's completion, hence this study is limited to assessing the difference between mandatory and voluntary cohorts in the middle of a transition to post-intervention equilibrium. The best this study can do with this limitation is to argue that there is no statistical difference between early mandatory adopters and voluntary adopters at the time of an asset's fourth NABERS Energy audit. But it was shown that voluntary adopters continue to improve up to an asset's sixth audit, so future research will be needed to better understand the post-intervention equilibrium relationship between voluntary and mandatory motivations to participate in an energy performance disclosure scheme.

Finally, this thesis has only considered Australian office assets. Chapter 2 argued that Australia was an ideal location to understand the effects of energy performance disclosure on property markets because NABERS Energy is a non-truncated scale, market penetration is high, and lease contracts are both publicly available and structurally consistent. In addition, the literature review found that asset-scale studies of green building premiums in Australia are comparable with the studies of the United States, implying some degree of transferability of these results to the United States and other similar markets. With the adoption of mandatory energy performance disclosure in some American states and cities, future comparative studies can assess the degree of transferability.

7.6 Concluding Summary

As discussed above, this thesis has made a number of contributions to real estate research. Policymakers and asset managers now have empirical evidence that environmental differentiation strategies induce private owners of existing assets to reduce energy consumption and its associated environmental impacts such as greenhouse gas emissions. Furthermore, it appears to be the knowledge of future audits that keeps the property market moving towards a more energy efficient equilibrium and there is no difference in outcomes based on the mechanism – voluntary or compulsory – that causes owners to begin energy auditing. As for how environmental differentiation affects property markets, this thesis found that removing some of the limitations on existing studies into green office rental prices changes the conclusion – at the very least in the Sydney market. Tenants do not appear to be willing to pay additional rent per square metre as a function of asset energy consumption or asset energy labels. A prospective theory developed to explain this finding finds weak financial and legal incentives for tenants to pay more to occupy energy efficient office space. Further research can test this theory using qualitative methods to explore tenant motivations.

From these research contributions arise implications for public policy and property practice. Policymakers now have a successful case study of implementing mandatory environmental disclosure in property markets, though such a strategy could also apply in other markets. Tenant unwillingness to pay for energy efficient accommodation suggests split incentives – an often discussed barrier to private investment in energy efficient asset improvements – may not be a hindrance at all. Property investors seeking an asset repositioning strategy are the ones most likely to profit from including energy efficiency into that strategy. Other investors can still profit from acquiring inefficient assets with the intent to upgrade, though this strategy carries additional risk because the profit appears to be associated with increased capital values, not income appreciation, so these investors must wait until the asset is sold. The lack of evidence that NABERS Energy certifications or intrinsic energy efficiency alters rental markets means that tenants can continue to use traditional valuation methods in market rent reviews since this study found over 85% of variation in rents can be explained through traditional measures of value.

Appendix 1

Alternate Dependent Variable to Model the Effect of NABERS Energy Participation on Operational Energy Consumption

Chapter 3 argued that the use of an asset's change in energy consumption relative to the initial benchmark (ΔP_j) was a more interesting dependent variable to understand the ability to explain the determinants of energy efficiency. The key reason is the alternative dependent variable, an asset's most recent energy consumption audit result ($P_{j_{s=max}}$) measured as Energy Use Intensity (EUI), provides a misleading sense of confidence in explanatory power. Equation 3.5 showed how ΔP_j is a linear transformation of $P_{j_{s=max}}$ so the coefficients of interest representing depth of NABERS Energy participation should be unaffected by the choice of dependent variable.

This appendix demonstrates that increase in explanatory power by specifying a model with the same independent variables as Equation 3.6, but with an independent variable of $P_{j_{s=max}}$:

$$P_{j_{s=max}} = \alpha + \boldsymbol{\beta_1 LOC_j} + \boldsymbol{\beta_2 AST_j} + \beta_3 CAP_j + \boldsymbol{\beta_4 OWN_j} + \beta_5 AVGDAYS_j + \boldsymbol{\beta_6 CERT_j} + \epsilon_j \quad \text{(A.1)}$$

Refer to Chapter 3 for a detailed explanation of these variables.

The results of this model are presented below in Table A.1 for all four specifications described in Chapter 3. As expected, variables representing depth of participation, asset location, asset characteristics, days between certificates and owner characteristics do not change from the results of the ΔP_j specification in Table 4.3. Identical coefficients and standard errors are presented in lighter grey type in Table A.1. Only the coefficient representing the variable for capacity to improve is different, although the standard error remains identical. However, the explanatory power of the model dramatically improves because of the stronger correlation between an asset's initial EUI and its most recent EUI.

Subtle differences in interpretation of the initial EUI variable result from the different specifications. In the ΔP_j specification, it is assumed that there is some theoretical equilibrium EUI for a given level of office accommodation services. Such an assumption is supported by the reduction in variance as NABERS participation increases and the significance of asset class variables representing differing levels of service in specification four (the Sydney subsample).

Table A.1. Regression results of Equation A.1 with a dependent variable of change in EUI between an asset's most recent measured EUI and its initial benchmark EUI. Standard error in brackets. Grey type indicates figures are identical to those in Table 4.3.

	Spec. 1 (All Obs.)	**Spec. 2 (All NLA Obs.)**	**Spec. 3 (Rated Hrs.)**	**Spec. 4 (Sydney CBD)**
Depth of Participation				
Two Certificates	*Reference*	*Reference*	*Reference*	*Reference*
Three Certificates	-1.38 (16.60)	-2.64 (17.01)	8.66 (19.08)	-207.73 (58.54) ***
Four Certificates	-77.00 (20.16) ***	-77.61 (20.7) ***	-66.98 (23.01) ***	-200.18 (63.99) ***
Five Certificates	-88.65 (23.17) ***	-87.62 (23.62) ***	-75.64 (25.07) ***	-242.51 (71.36) ***
Six Certificates	-128.20 (23.79) ***	-126.26 (24.53) ***	-111.27 (26.37) ***	-253.42 (65.25) ***
Seven Certificates	-129.77 (25.46) ***	-126.59 (26.18) ***	-114.25 (27.84) ***	-303.72 (68.14) ***
Eight Certificates	-118.54 (25.46) ***	-115.60 (26.13) ***	-100.87 (27.60) ***	-228.59 (67.86) ***
Asset Location				
State ACT	*Reference*	*Reference*	*Reference*	
State NSW	1.01 (29.77)	-2.44 (30.27)	-26.30 (36.89)	
State QLD	99.57 (36.59) ***	92.25 (37.2) **	80.03 (43.89) *	
State SA	10.42 (80.76)	-0.3 (81.39)	63.4 (175.14)	
State VIC	46.39 (33.67)	42.75 (34.11)	22.95 (40.18)	
State WA	-26.10 (46.85)	-39.69 (48.46)	-66.16 (57.93)	
State Other	-50.62 (69.61)	-71.09 (75.73)	-112.11 (105.48)	
CBD Canberra	24.38 (40.19)	17.24 (40.76)	-5.48 (51.22)	
CBD Sydney	-13.22 (19.14)	-8.82 (19.91)	-23.31 (21.51)	
CBD Brisbane	-71.55 (31.57) **	-64.85 (32.34) **	-86.05 (35.14) **	
CBD Adelaide	-52.23 (81.55)	-45.81 (82.46)	-128.27 (175.51)	
CBD Melbourne	-18.49 (27.59)	-12.02 (28.37)	-27.27 (29.72)	
CBD Perth	13.92 (45.29)	26.65 (47.03)	26.27 (53.20)	
CBD Other	-14.03 (80.46)	37.73 (94.90)	52.29 (126.12)	
Asset Characteristics				
Nat. Log. Asset NLA		-9.73 (9.17)	-12.91 (10.35)	21.35 (29.35)
Rated Hours (per week)			1.150 (0.904)	
Premium Grade				58.27 (51.42)
A-Grade				*Reference*
B- or C-Grade				110.25 (37.45) ***
Asset Age (in 2011)				-2.02 (1.06) **
Capacity to Improve				
Initial EUI	-0.658 (0.021) ***	-0.655 (0.021) ***	-0.642 (0.023) ***	-0.589 (0.064) ***
Owner Characteristics				
Green Power Purchased	-49.00 (18.78) ***	-46.25 (18.99) **	-49.01 (20.72) **	-115.18 (39.61) ***
Green Owner*Initial EUI	-0.079 (0.027) ***	-0.075 (0.028) ***	-0.083 (0.030) ***	-0.130 (0.046) ***
Avg. Days Between Certs. (Nat. Log.)	27.73 (14.66) *	31.24 (14.87) **	22.51 (17.42)	36.49 (43.45)
Intercept (α)	-3.35 (96.40)	69.34 (127.92)	118.07 (145.64)	-59.81 (337.54)
N	**818**	**806**	**696**	**119**
R-squared	**0.627**	**0.628**	**0.628**	**0.635**
Adj. R-squared	**0.616**	**0.617**	**0.614**	**0.586**

*, ** and *** indicate *p* values less than 0.10, 0.05, and 0.01 respectively.

Deviations from this theoretical equilibrium EUI as measured by the initial EUI can be interpreted as capacity to improve. However, the $P_{j_{s=max}}$ specification in this appendix relaxes the assumption about a theoretical equilibrium EUI and bundles additional characteristics into the variable for initial EUI (such as level of service). The best example of this bundling is the comparison between specification four in Table 4.3 and Table A.1; the additional asset characteristic data on age and level of service produces the lowest gap between *r*-squared figures. Using $P_{j_{s=max}}$ as the dependent variable in the Sydney subsample only produces a 10% gain in explanatory power as opposed to the 27% gain seen in other specifications. Hence it is more enlightening to unbundle the interpretation of the initial EUI variable.

Appendix 2

Descriptive statistics of additional lease database subsamples

Chapter 5 presented descriptive statistics of the entire lease database (Tables 5.2, 5.3 and 5.4) and the subsample of leases with disclosed signing incentives (Tables 5.5 and 5.6). This appendix describes subsamples of the database that are of interest for regression results presented in Appendix 3. First, the sample of net leases is presented, with rent described using both metrics – net face rent and semi-gross face rent – because estimated operating expenses are observed for each net lease. The next subsample is of all semi-gross leases. Descriptions are also provided for subsamples based on asset quality. The prime-grade subsample consists of all leases in Premium- and A-grade assets while the secondary-grade subsample contains all leases in B- and C-grade assets.

A2.1 Net and Semi-Gross subsamples

Table A.2 presents the continuous variables describing all observed net lease contracts (N=300), while Table A.3 describes all semi-gross lease contracts (N=373). There are significant differences in many comparable variables. Assets employing net lease contracts tend to be slightly larger and newer than those using semi-gross lease contracts. Because these assets are larger, the tenancy areas leased under net lease contracts are larger and the average floor height of a tenancy is higher relative to semi-gross contracts. semi-gross face rent calculated for net lease contracts by adding the base year operating expense to the net face rent is also significantly higher than observed in semi-gross lease contracts. Assets employing net lease structures are significantly younger than those using semi-gross leases. As for energy consumption, although asset energy intensity in net lease contracts is significantly lower than in semi-gross lease contracts, there is no significant difference in the distribution of NABERS Energy star ratings.

Binary variable descriptions are presented in Table A.4 for all subsamples in this appendix. Smaller submarket boundaries are not presented because of sample sizes for each subsample. For the differentiation between net and semi-gross lease contracts, there is little spatial differentiation between the two samples according to the PCA submarket definitions. However, there is a distinction in quality grading; assets using net lease contracts tend to provide higher quality services than those using semi-gross lease contracts.

A2.2 Prime and Secondary subsamples

It is conventional in market discussions of the central Sydney office market to group Premium- and A-grade assets as “prime” assets. Likewise, B- and C-grade assets are grouped as “secondary” assets. Tables A.5 and A.6 present descriptive statistics for prime and secondary asset subsamples. Binary variable statistics are presented for these groups in Table A.4.

Most of the differences between prime and secondary assets are unsurprising. Prime assets are larger, thus appeal to tenants seeking large multi-floor tenancies. Semi-gross face rent in prime assets is significantly larger than in secondary assets. Bank guarantees required for security in prime assets are larger. Tenants in prime assets sign longer lease terms than those in secondary assets. Prime assets are also significantly younger than secondary assets. In the binary variables captured for the lease database, prime assets are slightly more likely to be located in the City Core submarket, while secondary assets are slightly more numerous in the Western submarket. Lastly, as was observed above, prime assets are more likely to negotiate net lease contracts while Secondary assets tend to use semi-gross lease contracts.

There is little difference in the energy consumption characteristics between prime and secondary assets. Energy use intensity is indistinguishable between prime and secondary assets. The NABERS Energy ratings suggest that secondary properties are relatively more energy efficient compared with prime assets; this makes sense in the context that prime assets provide more services than secondary assets.

Table A.2. Descriptive Statistics for continuous variables. Net lease contracts only (N=300). Shaded variables are only available for net lease contracts, meaning a comparison with semi-gross contracts is not possible.

	Mean	Std. Dev.	Median	Minimum	Maximum
Tenancy Area (m^2)	1,149*	1,979	428	45	12,876
Asset Size (m^2 NLA)	35,133*	16,292	33,625	6,571	73,500
Asset Energy Intensity (MJ/m^2/year)	658*	213	629	274	1,540
Semi-Gross Face Rent (A$/m^2/year)	784*	215	724	445	1,446
Lease Term (months)	63.0*	27.5	60	12	134
Floor of Tenancy	18.6*	12.0	17	0	53
Number of Floors Leased	1.45	1.40	1	1	11
Bank Guarantee (months)	6.04*	4.87	6	0	35
NABERS Energy Rating at Time of Lease	2.82	1.41	3	0	5
Walking Distance to Train Station (m)	222	84.6	233	3	443
Building Age at Commencement (year)	25.8*	11.8	22	3	46
Net Face Rent (A$/m^2/year)	640	203	585	350	1,300
Base Year Operating Cost (A$/m^2/year)	144	20.3	144	90	196

* indicates significant difference at the 0.05 level between the cohort of net lease observations and the cohort of semi-gross leases.

Table A.3. Descriptive Statistics for continuous variables. Semi-gross lease contracts only (N=373).

	Mean	Std. Dev.	Median	Minimum	Maximum
Tenancy Area (m^2)	699*	1,625	301	29	24,141
Asset Size (m^2 NLA)	21,352*	17,915	15,564	2,917	85,551
Asset Energy Intensity (MJ/m^2/year)	710*	221	700	371	1,712
Semi-Gross Face Rent (A$/$m^2$/year)	608*	127	600	320	1,200
Lease Term (months)	55.9*	23.5	60	12	144
Floor of Tenancy	12.4*	10.7	10	0	65
Number of Floors Leased	1.26	1.56	1	1	27
Bank Guarantee (months)	4.85*	3.11	6	0	18
NABERS Energy Rating at Time of Lease	2.66	1.02	3	0	4.5
Walking Distance to Train Station (m)	210	123	222	15	430
Building Age at Commencement (year)	36.7*	17.9	35	9	129

* indicates significant difference at the 0.05 level between the cohort of net lease observations and the cohort of semi-gross leases.

Table A.4. Descriptive statistics for binary variables for all subsamples in this appendix. Percentage is the relative incidence of each star rating group within each group of independent binary variables. Integer is the number of assets (Percentage x N).

	Net Leases	Semi-Gross Leases	Prime Asset Leases	Secondary Asset Leases	All Leases
PCA Submarket					
City Core	52.3% (157)	59.2% (221)	63.2% (240)	47.1% (138)	56.1% (378)
Midtown	16.3% (49)	18.8% (70)	17.6% (67)	17.7% (52)	17.7% (119)
Western Corridor	29% (87)	21.7% (81)	17.1% (65)	35.2% (103)	25% (168)
Southern	2.4% (7)	0.3% (1)	2.1% (8)	- (0)	1.2% (8)
Quality Grade					
Premium	23.7% (71)	1.9% (7)	20.5% (78)	- (0)	11.6% (78)
A-Grade	53.7% (161)	37.8% (141)	79.5% (302)	- (0)	44.9% (302)
B-Grade	22.6% (68)	50.9% (190)	- (0)	88.1% (258)	38.3% (258)
C-Grade	- (0)	9.4% (35)	- (0)	11.9% (35)	5.2% (35)
Operating Expenses					
Net	100% (300)	- (0)	61.1% (232)	23.2% (68)	44.6% (300)
Semi-Gross	- (0)	100% (373)	38.9% (148)	76.8% (225)	55.4% (373)
N	**300**	**373**	**380**	**293**	**673**

Table A.5. Descriptive statistics for continuous variables. Prime asset lease contracts only (N=380).

	Mean	**Std. Dev.**	**Median**	**Minimum**	**Maximum**
Tenancy Area (m^2)	1,213*	2,196	540	29	24,141
Asset Size (m^2 NLA)	37,434*	18,466	37,300	3,110	85,551
Asset Energy Intensity (MJ/m^2/year)	678	188	664	319	1,146
Semi-Gross Face Rent (A$/$m^2$/year)	777*	202	731	445	1,446
Lease Term (months)	64.8*	28.60	60	12	144
Floor of Tenancy	19.1*	13.2	18	0	65
Number of Floors Leased	1.50*	1.88	1	1	27
Bank Guarantee (months)	5.94*	4.80	6	0	35
NABERS Energy Rating at Time of Lease	2.64*	1.23	3	0	4.5
Walking Distance to Train Station (m)	212	110	231	19	443
Building Age at Commencement (year)	27.1*	18.0	21	3	129

* indicates significant difference at the 0.05 level between the cohort of prime asset observations and the cohort of secondary asset observations.

Table A.6. Descriptive statistics for continuous variables. Secondary-asset lease contracts only (N=293).

	Mean	**Std. Dev.**	**Median**	**Minimum**	**Maximum**
Tenancy Area (m^2)	493*	965	228	37	10,571
Asset Size (m^2 NLA)	14,605*	7,139	15,057	2,917	46,583
Asset Energy Intensity (MJ/m^2/year)	698	253	700	274	1,712
Semi-Gross Face Rent (A$/$m^2$/year)	569*	89	583	320	750
Lease Term (months)	50.4*	18.4	48	20	120
Floor of Tenancy	10.0*	6.7	9	0	35
Number of Floors Leased	1.14*	0.7	1	1	7
Bank Guarantee (months)	4.66*	2.60	6	0	18
NABERS Energy Rating at Time of Lease	2.85*	1.17	3	0	5
Walking Distance to Train Station (m)	220	105	253	3	418
Building Age at Commencement (year)	37.9*	11.4	36	15	104

* indicates significant difference at the 0.05 level between the cohort of prime asset observations and the cohort of secondary asset observations.

Appendix 3

Models of additional lease database subsamples

For a more comprehensive exploration of the relationship between asset energy efficiency and rent prices, this appendix presents models based on Equation 5.5 for the four subsamples described in Appendix 2: net leases, semi-gross leases, prime assets, and secondary assets. Small subsamples mean only PCA submarket location specifications will be used. The intent of this appendix is to purposely bias the population to identify whether tenant demand for asset energy efficiency is a segmented market in Sydney.

One caveat to all these subsamples is the sharp reduction in observations relative to the entire population. In particular, net lease contracts (N=300) and secondary-grade assets (N=293) may suffer from the effects of small sample size. Binary variables representing individual star ratings in Specification 3 are susceptible to over-fitting as instrumental variables measuring an unobserved effect, especially in the event that only one or two assets are represented in a particular star rating. In this case, the estimated coefficient could be an instrument for the stochastic error trend common to all leases in these unique assets that may or may not reflect asset energy efficiency. As was the case in the effective rent model results in Chapter 6, discussion on these subsamples will concentrate on Specifications 2 and 4, which are less susceptible to over-fitting. Specification 3 is included in this appendix for comprehensiveness and is only referenced in the discussion when a consistent pattern emerges.

A3.1 Net Leases

The net lease subsample model estimation is presented in Tables A.7a and A.7b. This model is identical to Equation 5.5, but with one important exception that sets it apart from every other model of the Sydney office market presented in this paper. The dependent variable is the natural logarithm of net face rent, not semi-gross face rent. This choice has the added benefit of testing whether the need to convert every net rent into semi-gross rent has an effect on the relationship between energy efficiency and rental prices.

A notable result from the net lease model relative to the entire population is a weak indication of the expected negative association between energy performance and net rent. There is a significant net face rent premium for above average NABERS Energy ratings in Specification 2, while Specification 4 reveals a negative, but insignificant, coefficient for energy consumption, meaning that tenants pay lower rent as assets consume more energy, all else equal. Could this be a sign that grossing up all leases masks a rental premium for energy efficiency? Most likely, the emerging negative relationship between rent and energy consumption is the result of a strong association between net leases and prime assets (see Appendix 2). Instead of a signal that grossing-up net lease contracts hides the expected relationship between energy and rent, the net rent model could also be hinting that energy may only be valued by prime tenants. The prime asset subsample below that uses semi-gross face rent supports this latter explanation.

Table A.7a. Estimation of net lease subsample using Equation 5.5. Dependent variable is the natural logarithm of net face rent. N=300. Statistics are coefficient (t-value). Remaining parameters in Table A.7b.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			-0.023 (-0.52)		
1			-0.025 (-0.33)		
1.5			-0.109** (-2.02)		
2			-0.066 (-1.58)		
2.5			*Reference*		
3			0.007 (0.176)		
3.5			-0.005 (-0.11)		
4			-0.043 (-0.93)		
4.5 or 5			0.016 (0.288)		
Poor (0, 1, or 1.5)		0.004 (0.164)			
Below Average (2 or 2.5)		*Reference*			
Above Average (3 or 3.5)		0.045** (2.30)			
Best Practice (4, 4.5 or 5)		0.007 (0.242)			
Energy Consumption					
Energy Use Intensity (natural log)				-0.047 (-1.44)	
Top Consumption Quintile (least energy efficient)					*Reference*
2nd Consumption Quintile					-0.007 (-0.32)
3rd Consumption Quintile					0.036 (1.381)
4th Consumption Quintile					0.013 (0.519)
5th Consumption Quintile (most energy efficient)					0.029 (0.914)
Lease Term Length					
Short (4 years or less)	-0.018 (-1.28)	-0.014 (-0.95)	-0.017 (-1.14)	-0.021 (-1.43)	-0.019 (-1.25)
Average (5 years)	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Long (6 years or more)	-0.034* (-1.81)	-0.030 (-1.63)	-0.035* (-1.94)	-0.036* (-1.95)	-0.035* (-1.95)
Lowest Floor Leased	0.015*** (8.31)	0.015*** (8.42)	0.015*** (8.09)	0.015*** (8.32)	0.015*** (8.24)
Lowest Floor Leased Squared	-2.2x10^{-5} (-0.632)	-3.6x10^{-5} (-0.981)	-3.0x10^{-5} (-0.797)	-2.5x10^{-5} (-0.695)	-2.6x10^{-5} (-0.713)
Leased Area (natural log)	-0.003 (-0.47)	-0.004 (-0.51)	-0.001 (-0.16)	-0.002 (-0.27)	-0.003 (-0.37)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table A.7b. Continuation of Table A.7a, featuring regressor groups ***LOC, AST, MKT*** and goodness of fit measures for the net lease subsample.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.169*** (-8.322)	-0.163*** (-7.37)	-0.158*** (-7.158)	-0.169*** (-8.344)	-0.171*** (-7.962)
Western Corridor	-0.130*** (-6.282)	-0.132*** (-5.589)	-0.142*** (-5.887)	-0.141*** (-6.534)	-0.147*** (-6.109)
Southern	-0.373*** (-7.952)	-0.355*** (-6.314)	-0.388*** (-6.753)	-0.393*** (-7.382)	-0.380*** (-6.698)
Walking Distance to Train (natural log)	-0.043** (-2.384)	-0.045** (-2.303)	-0.048** (-2.572)	-0.049*** (-2.65)	-0.044** (-2.338)
Asset Service Quality					
Premium	0.195*** (8.540)	0.207*** (8.459)	0.192*** (8.138)	0.206*** (8.366)	0.198*** (8.438)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.068*** (-2.855)	-0.059** (-2.355)	-0.084*** (-3.237)	-0.078*** (-3.096)	-0.070*** (-2.737)
C-Grade	None in sample	None in sample	None in sample	None in sample	None in sample
Asset Vintage					
Heritage (>60 years old)	None in sample	None in sample	None in sample	None in sample	None in sample
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	0.068*** (3.915)	0.066*** (3.898)	0.063*** (3.697)	0.061*** (3.383)	0.064*** (3.567)
Commencement Half Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	0.006 (0.145)	0.006 (0.141)	0.012 (0.281)	0.008 (0.183)	0.006 (0.132)
January to June 2008	0.160*** (3.926)	0.150*** (3.799)	0.154*** (3.973)	0.155*** (3.825)	0.149*** (3.758)
July to December 2008	0.225*** (5.127)	0.219*** (5.128)	0.214*** (5.148)	0.220*** (5.052)	0.218*** (5.044)
January to June 2009	0.203*** (6.052)	0.194*** (6.010)	0.195*** (6.375)	0.194*** (5.639)	0.195*** (5.905)
July to December 2009	0.137*** (3.758)	0.122*** (3.396)	0.120*** (3.471)	0.129*** (3.450)	0.122*** (3.289)
January to June 2010	0.156*** (4.520)	0.145*** (4.346)	0.136*** (4.304)	0.149*** (4.229)	0.147*** (4.274)
July to December 2010	0.156*** (4.601)	0.148*** (4.451)	0.136*** (4.247)	0.146*** (4.214)	0.145*** (4.252)
January to June 2011	0.188*** (5.079)	0.178*** (4.940)	0.172*** (5.061)	0.177*** (4.675)	0.182*** (4.961)
July to December 2011	0.175*** (3.918)	0.158*** (3.556)	0.149*** (3.497)	0.164*** (3.583)	0.160*** (3.551)
Constant	6.273*** (56.76)	6.267*** (53.78)	6.318*** (58.77)	6.612*** (24.51)	6.274*** (56.69)
R-Squared	**0.885**	**0.888**	**0.893**	**0.886**	**0.887**
Adjusted R-Squared	**0.876**	**0.878**	**0.882**	**0.877**	**0.876**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Other notable changes include a young asset premium, a stronger long-term lease discount signal, and the highest explanatory power of all models in this study. Similar to the energy discussion above, all of these trends are repeated in the prime asset model described below. For example, the young asset premium arises because prime assets may have a young vintage value as a result of additional services beyond the PCA quality specifications or as a result of potential prestige value associated with being accommodated in the newest prime office tower. Because these similar trends occur in the prime asset model using semi-gross rent as the dependent variable, it can be concluded that the necessity of using semi-gross rent to model the entire population does not affect the results.

Table A.8a. Estimation of semi-gross lease subsample using Equation 5.5. Dependent variable is the natural logarithm of semi-gross face rent. N=373. Statistics are coefficient (t-value). Remaining parameters in Table A.8b.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			0.006 (0.16)		
1			-0.049** (-2.061)		
1.5			0.011 (0.431)		
2			0.025 (1.09)		
2.5			*Reference*		
3			0.030 (1.619)		
3.5			-0.002 (-0.09)		
4, 4.5 or 5			-0.014 (-0.83)		
Poor (0, 1, or 1.5)		-0.017 (-0.95)			
Below Average (2 or 2.5)		Reference			
Above Average (3 or 3.5)		0.012 (0.769)			
Best Practice (4, 4.5 or 5)		-0.016 (-1.11)			
Energy Consumption					
Energy Use Intensity (natural log)				0.017 (0.777)	
Top Consumption Quintile (least energy efficient)					*Reference*
2nd Consumption Quintile					0.020 (1.068)
3rd Consumption Quintile					0.020 (1.229)
4th Consumption Quintile					-0.013 (-0.56)
5th Consumption Quintile (most energy efficient)					-0.021 (-1.05)
Lease Term Length					
Short (4 years or less)	-0.011 (-0.92)	-0.011 (-0.96)	-0.014 (-1.21)	-0.011 (-1.00)	-0.012 (-1.01)
Average (5 years)	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Long (6 years or more)	-0.008 (-0.54)	-0.008 (-0.551	-0.011 (-0.70)	-0.009 (-0.61)	-0.008 (-0.51)
Lowest Floor Leased	0.010*** (8.240)	0.009*** (8.048)	0.010*** (8.261)	0.010*** (8.286)	0.009*** (7.959)
Lowest Floor Leased Squared	-4.8x10^{-5} ** (-2.454)	-4.8x10^{-5} ** (-2.339)	-5.0x10^{-5} ** (-2.509)	-4.8x10^{-5} ** (-2.454)	-4.5x10^{-5} ** (-2.298)
Leased Area (natural log)	-0.009 (-1.550	-0.009 (-1.41)	-0.008 (-1.31)	-0.009 (-1.49)	-0.008 (-1.34)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table A.8b. Continuation of Table A.8a, featuring regressor groups ***LOC*, *AST*, *MKT*** and goodness of fit measures for the semi-gross lease subsample.

Independent Variable	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**	**Spec. 5**
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.116*** (-6.995)	-0.120*** (-6.741)	-0.116*** (-6.533)	-0.114*** (-6.915)	-0.104*** (-6.006)
Western Corridor	-0.102*** (-7.228)	-0.110*** (-6.812)	-0.099*** (-6.259)	-0.100*** (-6.866)	-0.094*** (-6.168)
Southern	-0.371*** (-13.192)	-0.390*** (-11.463)	-0.404*** (-10.318)	-0.372*** (-13.246)	-0.362*** (-10.476)
Walking Distance to Train (natural log)	-0.015*** (-2.900)	-0.014** (-2.490)	-0.013** (-2.026)	-0.014*** (-2.651)	-0.011** (-2.073)
Asset Service Quality					
Premium	0.329*** (8.933)	0.315*** (7.600)	0.313*** (7.492)	0.328*** (8.948)	0.337*** (8.414)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
B-Grade	-0.105*** (-7.589)	-0.111*** (-7.819)	-0.116*** (-7.981)	-0.109*** (-6.991)	-0.118*** (-7.232)
C-Grade	-0.436*** (-16.426)	-0.444*** (-16.083)	-0.457*** (-16.309)	-0.438*** (-16.452)	-0.441*** (-15.247)
Asset Vintage					
Heritage (>60 years old)	0.055* (1.836)	0.065** (2.25)	0.070** (2.322)	0.058* (1.942)	0.059** (2.07)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	-0.012 (-0.554)	-0.011 (-0.481)	-0.008 (-0.344)	-0.012 (-0.536)	-0.014 (-0.658)
Commencement Half Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	0.014 (0.437)	0.01 (0.286)	0.003 (0.072)	0.019 (0.570)	0.014 (0.397)
January to June 2008	0.109*** (3.461)	0.101*** (3.154)	0.093*** (2.625)	0.113*** (3.650)	0.108*** (3.349)
July to December 2008	0.128*** (3.895)	0.127*** (3.842)	0.114*** (3.131)	0.132*** (4.089)	0.131*** (3.915)
January to June 2009	0.123*** (3.093)	0.117*** (2.934)	0.105** (2.508)	0.128*** (3.253)	0.122*** (3.013)
July to December 2009	0.093** (2.578)	0.088** (2.379)	0.074* (1.831)	0.098*** (2.668)	0.094** (2.478)
January to June 2010	0.148*** (4.784)	0.144*** (4.461)	0.137*** (3.759)	0.154*** (5.000)	0.160*** (4.920)
July to December 2010	0.163*** (5.533)	0.158*** (5.154)	0.149*** (4.295)	0.169*** (5.707)	0.175*** (5.578)
January to June 2011	0.176*** (5.933)	0.175*** (5.603)	0.170*** (4.810)	0.181*** (6.029)	0.188*** (5.923)
July to December 2011	0.179*** (5.810)	0.179*** (5.536)	0.169*** (4.532)	0.183*** (6.131)	0.196*** (5.971)
Constant	6.421*** (118.8)	6.422*** (111.7)	6.416*** (104.0)	6.296*** (37.66)	6.387*** (117.9)
R-Squared	**0.793**	**0.795**	**0.800**	**0.793**	**0.796**
Adjusted R-Squared	**0.779**	**0.780**	**0.783**	**0.779**	**0.780**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

A3.2 Semi-Gross Leases

The semi-gross lease subsample model estimation is presented in Tables A.8a and A.8b. Semi-gross face rent returns as the independent variable, making this estimation identical to Equation 5.5, but with all 300 net lease contracts removed, leaving a sample size of 373.

In general, the model of this subsample matches the entire population with only marginal differences. Discounts based on lease term length reduce to the degree that the model sees them as statistically indifferent from zero. In addition, Premium-grade assets offering semi-gross lease contracts appear to extract a much larger premium based on asset service quality than the population as a whole. However, caution in interpreting this is warranted because only one Premium-grade asset in the database offers a semi-gross lease contract, thus the coefficient could also be measuring a unobserved quality in that one asset on top of its premium service quality. Perhaps the biggest difference between the semi-gross subsample and the entire population is the relatively low (but still nominally high) explanatory power of the semi-gross lease cohort compared with the net lease cohort or the population as a whole. Finally, as is the case in the model of the whole population, there is no consistent pattern between energy consumption variables and face rent in semi-gross leases.

A3.3 Prime Assets

A model of all lease transactions in prime assets (Premium- and A-grade quality ratings) is presented in Tables A.9a and A.9b. The dependent variable is the natural logarithm of semi-gross face rent. In total, 380 of the 673 lease transactions in the database occur in prime assets.

Prime assets display the most consistent negative relationship between energy consumption and face rent of any subsample. Although most coefficients are statistically indifferent from zero, the coefficients for binary variables representing NABERS Ratings are generally negative below the market average and positive above the market average. The strongest signal of the integration between energy consumption and face rent is the continuous variable in Specification 4 representing audited energy consumption. A negative, and statistically significant, coefficient indicates the expected negative relationship between energy consumption and face rent; high energy consumption is associated with lower face rent. The binary variables in Specification 5 demonstrate more specifically that the signal from the continuous variable is one of discounts for energy inefficient assets because there is little differentiation in face rent prices amongst the three most energy efficient quintiles.

Table A.9a. Estimation of prime asset subsample using Equation 5.5. Dependent variable is the natural logarithm of semi-gross face rent. N=380. Statistics are coefficient (t-value). Remaining parameters in Table A.9b.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			-0.020 (-0.75)		
1			-0.049 (-1.52)		
1.5			-0.030 (-0.90)		
2			-0.022 (-1.02)		
2.5			Reference		
3			0.015 (0.770)		
3.5			0.009 (0.453)		
4			-0.013 (-0.59)		
4.5 or 5			0.071 (1.538)		
Poor (0, 1, or 1.5)		-0.020 (-1.18)			
Below Average (2 or 2.5)		Reference			
Above Average (3 or 3.5)		0.026** (2.06)			
Best Practice (4, 4.5 or 5)		0.005 (0.307)			
Energy Consumption					
Energy Use Intensity (natural log)				-0.050** (-2.252)	
Top Consumption Quintile (least energy efficient)					Reference
2nd Consumption Quintile					0.008 (0.457)
3rd Consumption Quintile					0.042** (2.39)
4th Consumption Quintile					0.033* (1.836)
5th Consumption Quintile (most energy efficient)					0.038* (1.877)
Oper. Expense Liability					
Net Lease	0.081*** (8.539)	0.081*** (8.213)	0.078*** (7.310)	0.087*** (8.741)	0.085*** (8.263)
Semi-Gross Lease	Reference	Reference	Reference	Reference	Reference
Lease Term Length					
Short (4 years or less)	-0.020* (-1.937)	-0.021** (-2.016)	-0.022** (-2.012)	-0.022** (-2.083)	-0.023** (-2.166)
Average (5 years)	Reference	Reference	Reference	Reference	Reference
Long (6 years or more)	-0.026** (-1.972)	-0.025* (-1.962)	-0.029** (-2.202)	-0.027** (-2.120)	-0.027** (-2.145)
Lowest Floor Leased	0.014*** (11.19)	0.014*** (10.97)	0.014*** (11.02)	0.014*** (11.16)	0.014*** (11.03)
Lowest Floor Leased Squared	$-7.4x10^{-5}$ *** (-3.550)	$-7.7x10^{-5}$ *** (-3.598)	$-8.2x10^{-5}$ *** (-3.737)	$-7.6x10^{-5}$ *** (-3.576)	$-7.6x10^{-5}$ *** (-3.533)
Leased Area (natural log)	-0.004 (-0.71)	-0.004 (-0.75)	-0.003 (-0.59)	-0.003 (-0.62)	-0.004 (-0.70)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table A.9b. Continuation of Table A.9a, featuring regressor groups ***LOC***, ***AST***, ***MKT*** and goodness of fit measures for the prime asset subsample.

Independent Variable	**Spec. 1**	**Spec. 2**	**Spec. 3**	**Spec. 4**	**Spec. 5**
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.144*** (-9.602)	-0.141*** (-9.266)	-0.141*** (-8.705)	-0.143*** (-9.467)	-0.140*** (-8.937)
Western Corridor	-0.126*** (-9.291)	-0.132*** (-9.336)	-0.136*** (-9.275)	-0.134*** (-9.493)	-0.139*** (-9.515)
Southern	-0.350*** (-11.849)	-0.346*** (-10.496)	-0.385*** (-10.915)	-0.361*** (-11.506)	-0.351*** (-10.624)
Walking Distance to Train (natural log)	-0.006 (-0.833)	-0.005 (-0.786)	-0.004 (-0.522)	-0.006 (-0.938)	-0.004 (-0.533)
Asset Service Quality					
Premium	0.206*** (10.97)	0.219*** (11.43)	0.208*** (10.52)	0.216*** (11.16)	0.213*** (11.15)
A-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Asset Vintage					
Heritage (>60 years old)	0.064** (2.509)	0.068*** (2.658)	0.078*** (2.936)	0.056** (2.179)	0.061** (2.279)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	0.042*** (3.174)	0.036*** (2.735)	0.041*** (3.029)	0.036*** (2.642)	0.035** (2.528)
Commencement Half Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	-0.029 (-1.020)	-0.032 (-1.079)	-0.035 (-1.148)	-0.033 (-1.115)	-0.03 (-1.005)
January to June 2008	0.115*** (4.245)	0.102*** (3.652)	0.100*** (3.476)	0.107*** (3.876)	0.102*** (3.662)
July to December 2008	0.171*** (5.636)	0.164*** (5.310)	0.162*** (5.008)	0.163*** (5.415)	0.164*** (5.368)
January to June 2009	0.162*** (6.151)	0.146*** (5.273)	0.151*** (5.406)	0.149*** (5.401)	0.148*** (5.409)
July to December 2009	0.098*** (3.503)	0.083*** (2.773)	0.085*** (2.786)	0.084*** (2.840)	0.081*** (2.702)
January to June 2010	0.151*** (6.237)	0.137*** (5.257)	0.135*** (5.081)	0.138*** (5.359)	0.137*** (5.241)
July to December 2010	0.145*** (5.909)	0.130*** (4.904)	0.125*** (4.596)	0.129*** (4.950)	0.127*** (4.767)
January to June 2011	0.165*** (6.216)	0.150*** (5.348)	0.149*** (5.191)	0.149*** (5.377)	0.148*** (5.296)
July to December 2011	0.154*** (4.340)	0.137*** (3.612)	0.133*** (3.562)	0.137*** (3.625)	0.134*** (3.560)
Constant	6.284*** (126.6)	6.296*** (126.5)	6.293*** (121.8)	6.625*** (41.53)	6.269*** (127.6)
R-Squared	**0.868**	**0.872**	**0.874**	**0.870**	**0.872**
Adjusted R-Squared	**0.860**	**0.863**	**0.863**	**0.862**	**0.862**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Other than the signals associated with energy efficiency, the only other notable differences between the prime asset subsample and the population as a whole are the consistency of discounts as a function of lease-term length (long and short) and a vintage premium for young assets. This latter observation hints at the presence of a prestige effect for prime asset tenants to be located in the newest office buildings or the possibility that newer assets provide services above the criteria for Premium-grade classification. In all other model specifications besides the net lease subsample, which is highly influenced by prime assets, the asset quality ratings are able to account for price differentiations in non-heritage assets.

A3.4 Secondary Assets

The final subsample, leases in secondary assets (B- and C-grade quality ratings), is modelled in Tables A.10a and A.10b using Equation 5.5. The dependent variable remains the natural logarithm of semi-gross face rent. Of the total 673 lease transactions in the database, 293 of them are for accommodation in secondary assets.

Results show that the secondary asset market segment is less predictable and uniform than the prime asset market. Equation 5.5 can only explain approximately 70% of the variation in semi-gross face rent for this cohort, as compared with 86% of the prime-grade sector. One explanation for this lies in the manner that the official Property Council of Australia quality rating guidelines create a relatively homogenous prime asset market while allowing greater flexibility at the secondary end. To qualify for a Premium-grade rating, an asset owner must fulfil all requirements of an A- and B-Grade asset, plus the additional criteria for Premium-grade classification. Thus high-grade assets are relatively uniform as a result of a high degree of voluntary regulation, while low-grade assets operate with much greater flexibility in the manner they are positioned in the market. Another reason for a differential in explanatory power is a diversity of ownership among secondary assets that is more heterogeneous in relation to prime-grade office asset ownership (which in Sydney is primarily large professional investment firms). Hence there is more differentiation potential – service quality and ownership characteristics – amongst B- and C-grade assets than amongst Premium- and A-grade assets.

As for energy efficiency in secondary assets, the inconsistent relationship with face rent returns. If anything, very high energy efficiency as expressed through best-practice NABERS Energy ratings in secondary assets reduces face rent. This is likely to be a weak signal related to the role of energy as a factor of production in office accommodation services. Above, it was discussed that secondary assets qualify for this definition because they lack services that define prime assets. For example, qualification for an A-Grade designation is a binary outcome, either an asset possesses all the criteria or not. It logically follows that energy consumption could act as a proxy for partial provision of A-Grade services. Secondary assets with low energy consumption may not be energy efficient as defined through provision of the same amount of services using less energy, but rather energy efficient as a result of less service provision. Energy use as a proxy for partial

A-Grade service provision explains why tenants would pay lower rents in assets that consume less energy (high NABERS Energy ratings) and higher rents in assets that consume more energy (low NABERS Energy ratings).

Tenancy height is not as valued in secondary assets as it is in prime assets. The relatively small size of secondary assets is the reason behind this observation (see Tables A.5 and A.6 in Appendix 2). Secondary assets are likely not big enough to offer expansive views.

Table A.10a. Estimation of secondary asset subsample using Equation 5.5. Dependent variable is the natural logarithm of semi-gross face rent. N=293. Statistics are coefficient (t-value). Remaining parameters in Table A.10b.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
NABERS Energy Rating					
0			0.045 (0.972)		
1			-0.068*** (-2.70)		
1.5			-0.005 (-0.179)		
2			0.018 (0.556)		
2.5			*Reference*		
3			0.008 (0.343)		
3.5			-0.044* (-1.82)		
4			-0.053** (-1.99)		
4.5 or 5			-0.044 (-1.336)		
Poor (0, 1, or 1.5)		-0.009 (-0.358)			
Below Average (2 or 2.5)		Reference			
Above Average (3 or 3.5)		-0.014 (-0.596)			
Best Practice (4, 4.5 or 5)		-0.060** (-2.25)			
Energy Consumption					
Energy Use Intensity (natural log)				0.041 (1.332)	
Top Consumption Quintile (least energy efficient)					Reference
2nd Consumption Quintile					0.009 (0.369)
3rd Consumption Quintile					-0.003 (-0.170)
4th Consumption Quintile					-0.057** (-2.24)
5th Consumption Quintile (most energy efficient)					-0.056** (-2.11)
Oper. Expense Liability					
Net Lease	0.079*** (3.227)	0.111*** (3.732)	0.093*** (2.891)	0.088*** (3.355)	0.106*** (3.898)
Semi-Gross Lease	Reference	Reference	Reference	Reference	Reference
Lease Term Length					
Short (4 years or less)	-0.020 (-1.572)	-0.016 (-1.217)	-0.018 (-1.340)	-0.022* (-1.69)	-0.021* (-1.66)
Average (5 years)	Reference	Reference	Reference	Reference	Reference
Long (6 years or more)	-0.022 (-1.220)	-0.023 (-1.279)	-0.029 (-1.586)	-0.027 (-1.478)	-0.029 (-1.644)
Lowest Floor Leased	0.008** (2.522)	0.007** (2.411)	0.007** (2.242)	0.008** (2.582)	0.008** (2.582)
Lowest Floor Leased Squared	$-1.6\text{x}10^{-5}$ (-0.165)	$2.0\text{x}10^{-6}$ (0.021)	$1.9\text{x}10^{-5}$ (0.203)	$-1.2\text{x}10^{-5}$ (-0.124)	$-9.3\text{x}10^{-6}$ (-0.098)
Leased Area (natural log)	-0.015** (-1.997)	-0.012* (-1.610)	-0.012 (-1.537)	-0.014* (-1.871)	-0.012 (-1.576)

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

Table A.10b. Continuation of Table A.10a, featuring regressor groups ***LOC, AST, MKT*** and goodness of fit measures for the secondary asset subsample. N=293.

Independent Variable	Spec. 1	Spec. 2	Spec. 3	Spec. 4	Spec. 5
PCA Submarket					
City Core	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Midtown	-0.106*** (-5.677)	-0.096*** (-4.439)	-0.104*** (-5.024)	-0.101*** (-5.595)	-0.099*** (-5.188)
Western Corridor	-0.088*** (-4.448)	-0.078*** (-3.332)	-0.068*** (-2.893)	-0.077*** (-3.689)	-0.074*** (-3.657)
Southern	None in sample	None in sample	None in sample	None in sample	None in sample
Walking Distance to Train (natural log)	-0.027*** (-2.998)	-0.023** (-2.345)	-0.018 (-1.472)	-0.022** (-2.135)	-0.019** (-2.102)
Asset Service Quality					
B-Grade	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
C-Grade	-0.332*** (-12.036)	-0.338*** (-12.294)	-0.355*** (-12.048)	-0.331*** (-12.042)	-0.316*** (-9.876)
Asset Vintage					
Heritage (>60 years old)	0.109** (2.495)	0.107*** (2.674)	0.112*** (2.681)	0.118*** (2.786)	0.113*** (2.730)
30 to 60 years old	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
Young (<30 years old)	-0.046 (-1.303)	-0.048 (-1.325)	-0.056 (-1.479)	-0.046 (-1.297)	-0.054 (-1.621)
Commencement Half Yr.					
January to June 2007	*Reference*	*Reference*	*Reference*	*Reference*	*Reference*
July to December 2007	0.103*** (3.537)	0.102*** (3.220)	0.098*** (3.138)	0.109*** (3.718)	0.106*** (3.337)
January to June 2008	0.167*** (6.050)	0.161*** (5.361)	0.159*** (5.126)	0.172*** (6.164)	0.166*** (5.747)
July to December 2008	0.208*** (7.843)	0.203*** (7.670)	0.201*** (7.585)	0.211*** (8.177)	0.204*** (7.755)
January to June 2009	0.183*** (5.588)	0.182*** (5.320)	0.187*** (5.521)	0.190*** (5.763)	0.182*** (5.323)
July to December 2009	0.185*** (7.671)	0.179*** (5.841)	0.173*** (5.063)	0.192*** (7.226)	0.178*** (6.022)
January to June 2010	0.180*** (9.726)	0.183*** (8.351)	0.181*** (7.631)	0.188*** (9.852)	0.188*** (9.025)
July to December 2010	0.220*** (13.14)	0.218*** (11.19)	0.212*** (8.722)	0.226*** (13.33)	0.229*** (12.06)
January to June 2011	0.238*** (13.20)	0.240*** (11.18)	0.246*** (9.390)	0.242*** (13.12)	0.244*** (11.64)
July to December 2011	0.247*** (12.32)	0.247*** (10.78)	0.231*** (8.198)	0.246*** (12.74)	0.259*** (10.49)
Constant	6.366*** (79.97)	6.341*** (71.74)	6.315*** (68.53)	6.053*** (23.82)	6.307*** (79.83)
R-Squared	**0.707**	**0.713**	**0.725**	**0.710**	**0.721**
Adjusted R-Squared	**0.684**	**0.688**	**0.695**	**0.686**	**0.695**

*, **, *** indicates statistical significance at the 90%, 95%, and 99% confidence levels respectively.

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