Incentives for Information Provision: Energy Efficiency in the Spanish Rental Market

Xueying Bian *and Natalia Fabra‡

November 07, 2018

Abstract

We build a search model with asymmetric information regarding houses' energy efficiency. The objective is to shed light on the house owners' incentives to obtain and disclose energy certificates (ECs) in the rental market. Such incentives depend not only on the rent premium for more efficient houses - as has been widely documented - but also on the rent penalty for unlabeled houses. Interestingly, we show that such a penalty is higher the greater the disclosure rate of ECs. The theoretical predictions are empirically quantified in the context of the Spanish rental market.

Keywords: Asymmetric information, energy efficiency, adoption rate, rental market

*Singapore Management University. Email: xybian.2016@phdecons.smu.edu.sg

†Universidad Carlos III de Madrid and CEPR. Email:natalia.fabra@uc3m.es

‡We are indebted to Cemfi for their hospitality while working on this paper. Imelda and Luisa Dressler provided helpful suggestions. Fabra is grateful to Fundacion BBVA and the Spanish Ministry of Education (Grant ECO2016-78632-P) for financial support.

1. Introduction

Improvements in energy efficiency are expected to be key in reducing energy consumption and global carbon emissions. Yet, and despite substantial policy support to energy efficiency programs,[1] the energy savings actually achieved lag behind expectations. This applies to a broad range of settings, including schools (Burlig et al., 2017), commercial buildings (Kok et al., 2011), or the residential sector (Fowlie et al., 2018), among others. Imperfect information stands as one of the most salient reasons for why agents fail to exploit profitable investments in energy efficiency.[2] For instance, in the rental market, landlords face weak incentives to invest in energy efficiency whenever lack of reliable information about the house's energy efficiency makes tenants unwilling to pay more for more efficient houses. Thus, failure to capitalize energy efficiency investment leads landlords to underinvest (Myers, 2015).

In order to address this market failure, most jurisdictions have introduced energy certificate (EC) programs that provide reliable information about the dwellings' energy efficiency. Several empirical studies have confirmed the existence of an efficiency rent premium that allows landlords to cash in the returns of their investments. This is true for the commercial building sector (Kok et al. (2011) and Eichholtz et al. (2010) as well as for the residential sector (Ramos et al. (2015), Dressler and Cornago (2017), Fuerst and Warren-Myers (2018)). Yet, despite the gains that many landlords would obtain from disclosing their ECs, disclosure rates are still low in most residential markets, even in those in which disclosure is mandatory. This paper combines a theory model and empirical evidence to explore (i) the reasons underlying the low disclosure rates of ECs in the rental market, and (ii) the link between the initial disclosure rates and the incentives for further disclosure.

Most of the existing papers on this topic focus on the incremental rents obtained by more efficient houses relative to the less efficient ones. This type of analysis measures landlords' incentives to improve energy efficiency *conditional on* having an EC. However, even if compulsory, landlords may have incentives (i) not to obtain the EC in order to save time and costs, or (ii) not to disclose it whenever the EC would reveal that the house has low energy efficiency. Hence, when assessing the impact of ECs, it is important to take into account the potential selection bias that these incentives create. Fuerst and Warren-Myers (2018) show that correcting for this selection bias amplifies the price differences between houses with low and high efficiency ratings. In their empirical analysis of the Australian residential rental market, they show that the rental prices for the most efficient houses are, after controlling for all other relevant factors, 3.5% higher as compared to a reference average rating. In contrast, houses with no EC are rented with a 1.13% penalty as compared to houses with the reference rating.

From a theoretical perspective, in order to uncover this prediction, one needs to relax the

[1] For instance, the European Union relies on the "energy efficiency first" principle that requires all energy-related policy-making and investment decisions to prioritize energy saving solutions over any other.

[2] Other explanations include capital market imperfections, split incentive problems, and behavioral biases (Allcott and Greenstone, 2012; Gerarden et al., 2017).

assumption that information is costless. Otherwise, Milgrom (1981)'s unraveling equilibrium would prevail, resulting in full disclosure: no individual household would have incentives to hide the EC as doing so would signal that the house has the lowest energy efficiency rate. However, Milgrom (1981)'s equilibrium with full disclosure breaks down whenever it is costly to obtain the EC. The reason is that not displaying the EC need not necessarily signal low energy efficiency but rather a high cost of obtaining the EC. In turn, since market frictions avoid full unraveling, the disclosure rate affects the incentives to obtain the certificates through the rent penalty faced by those who do not display them.

In this paper, we uncover these effects through the lens of a simple model that captures the incentives for the disclosure of energy certificates (ECs) in the rental market, including the impact on rental prices of both the labeled as well as the unlabeled houses. We combine (i) a search model for price formation under monopolistic competition,[3] with (ii) a model of asymmetric information between landlords and tenants regarding the house's energy efficiency. We assume monopolistic competition in the rental market since (i) there are typically many differentiated houses for rent, (ii) each house is negligible on its own, so that landlords ignore their impact on the market price, and (iii) each landlord faces a downward sloping demand and hence retains significant market power. We use this model to derive predictions about the rental prices of the houses with and without ECs, shedding light on the landlords' incentives to obtain and disclose them.

First, we analyze the case of search frictions but perfect information regarding the houses' energy efficiency: tenants can perfectly observe the energy efficiency of the houses once they visit them. We find that more energy efficient houses are rented at a premium, which is not affected by search costs nor the average energy efficiency in the housing market. Even if an increase in search costs and a reduction in the average energy efficiency of the houses in the local market increases rental prices, the energy efficiency premium remains constant because the price effects are uniform across houses.

This prediction changes when we add information frictions: tenants observe the house's energy efficiency only when the landlord has decided to obtain and disclose the EC. Since obtaining the EC has a cost, not all landlords decide to obtain one. In particular, only those landlords whose adoption costs are below the rent premium plus the expected fine in case of no adoption will obtain one. In turn, this implies that some efficient houses are pooled with the inefficient ones without an EC, thus stopping information unraveling. In this case, the average efficiency of the houses in the local market affects the search process, and through this, it has an impact on the rent efficiency premium.

Our model predicts that an exogenous increase in the costs of non-compliance (e.g. increased probability of inspection, increased fines, increased awareness of the obligation to disclose ECs) would trigger a reduction in the rental prices of those houses whose landlords endogenously decide not to adopt or not to show their ECs. In turn, this rent effect would increase the fraction of houses

[3] Our search model builds upon the model by Armstrong et al. (2009) (AVZ thereafter), which extends the seminal work of Wolinsky (1986) to allow for differences in quality among firms.

that obtain and disclose their EC.

In this context, an increase in expected fines is more effective in encouraging the disclosure of ECs than in standard models. Disclosure rates increase because of the pure cost-related effect (landlords without an EC face higher fines) but also, through the effects on the pool of houses that do not adopt and disclose their EC, because of the increase in the rent premium. Similar effects would arise if the distribution of the costs of obtaining the ECs would shift down (e.g. triggered by more intense competition among the certifiers). This suggests that subsidizing ECs could strengthen the incentives for disclosure, even if some of the landlords that obtained them at a reduced rate still decide to hide them.

We illustrate the findings of the model in the context of the Spanish housing rental market. Exploiting detailed information about the houses for rent from the commercial website Idealista, we fit modified hedonic models using Heckman's two-step method (Heckman, 1979) to deal with potential self-selection among the labeled houses. As suggested by the theoretical model, our empirical analysis incorporates characteristics of the local housing market as these affect the incentives to obtain and disclose ECs, as well as the prices at which labeled and unlabeled houses can be rented. We find that the most efficient houses (with A or B labels) obtain a 7% rent premium as compared to the least efficient houses (with F or G labels), while the efficiency rent premium of houses with labels C, D or E is 5%; both premia are statistically significant at the 10% level. Interestingly, we find that the rental prices for unlabeled houses significantly decrease with the disclosure of ECs in the local market. In particular, a 1% increase in the disclosure rate triggers a 6% reduction in the rental price.

The reminder of the paper is organized as follows. In section 2, we describe and analyze a model of search with asymmetric information to study the incentives for the adoption and disclosure of ECs. In section 3 we describe our data set composed of online ads about rental houses across various Spanish cities. In section 4 we empirically test the predictions of the model, and in section 5 we conclude.

2. The Model

Consider a rental market in which there is a mass of consumers normalized to one. Each consumer wants to rent a house in a market in which there are n houses for rent, with n tending to infinity (*monopolistic competition*). The consumers' net utility from renting a house $i \in \{1, ..., n\}$, with rental price p_i, is given by $u_i - p_i$. The term u_i captures the consumer's idiosyncratic utility (or *match utility*) from renting the house, which is assumed to be an *i.i.d.* draw from a uniform distribution in the interval $[0, \theta]$, where the parameter θ measures the house's energy efficiency. Therefore, when θ is known, the higher the house's energy efficiency, the higher the consumer's expected utility from renting it (thus capturing the fact that higher energy efficiency implies lower energy bills). In turn, the distribution of energy efficiency θ in the population of houses is uniform in the interval $[\underline{\theta}, 1]$. Hence, the average energy efficiency of the houses in the market, denoted $\widetilde{\theta}$, is increasing in $\underline{\theta}$.

When θ is not known, all the houses are ex ante identical from the point of view of consumers (as match utilities and energy efficiencies are drawn from common distributions). However, houses are ex-post differentiated as, once the customer has visited a house, he is able to observe his realized match utility. At each visit, the consumer incurs a search cost $s > 0$. The consumer visits houses sequentially: he visits houses randomly until he decides to stop searching. The consumer has the option to rent any of the houses he has visited.

We first analyze the case in which tenant can perfectly observe the energy efficiency of the house, θ, after visiting it. We will then consider the case in which θ is observable only if the landlord has decided to obtain and disclose the EC.

Equilibrium pricing when energy efficiency is observable First, assume that a tenant can observe θ upon visiting a house. Let V denote the consumer's equilibrium expected value from searching in this market. The consumer optimally stops searching as soon as he finds a house that gives him utility $u - p \geq V$, where V is implicitly defined so that the expected gain from an additional visit equals the search cost s,

$$\frac{1}{1-\underline{\theta}} \int_{\underline{\theta}}^{1} \left(\frac{1}{\theta} \int_{p+V}^{\theta} (u - p - V)\, du \right) d\theta = s. \tag{1}$$

Landlords choose their prices p so as to maximize expected profits given by the rental price times the probability of renting the house, $p \Pr(u - p \geq V)$. Maximization with respect to the price implies

$$p = \frac{\theta - V}{2}. \tag{2}$$

Intuitively, since the higher the house's energy efficiency the more likely it is that the tenant will stop searching, the rental price is increasing in θ. In equilibrium, the difference in the rental prices of two houses with energy efficiencies θ' and θ, with $\theta' > \theta$, is simply given by $(\theta' - \theta)/2 > 0$. It follows that more efficient houses are rented at higher prices.

Plugging the equilibrium price into the probability of renting the house shows that more efficient houses are also more likely to be rented out, despite their higher prices. Formally, the landlord's expected profits (conditionally on a consumer visiting the house) are given by

$$\pi = \frac{1}{\theta} \left(\frac{\theta - V}{2} \right)^2. \tag{3}$$

Since these profits are increasing in θ, the owners of more efficient houses also have higher expected profits.

Plugging the equilibrium price (2) into expression (1) and solving it for V shows that in equilibrium, the consumer's equilibrium expected value from searching is given by[4]

$$V = \left(\frac{1}{1-\underline{\theta}}\ln\frac{1}{\underline{\theta}}\right)^{-1}\left(1-\sqrt{1-\frac{\frac{1+\underline{\theta}}{2}-8s}{1-\underline{\theta}}\ln\frac{1}{\underline{\theta}}}\right). \tag{4}$$

As it is intuitive, V is decreasing in the search cost s. Hence, rental prices and profits are higher in markets with higher search costs. Search costs affect all prices equally (and only through V) so that the rental price differences across houses with different energy efficiencies remain constant. However, higher search costs lead to higher profit increases for energy efficient houses relatively to the less efficient ones. The reason is that the likelihood of renting the more efficient houses goes up.

Inspection of equation (4) also shows that V is increasing in the energy efficiency of the least efficient houses $\underline{\theta}$. A higher, $\underline{\theta}$ reflects two confounding effects: on the one hand, it means that the average energy efficiency of the houses in the market is higher, which implies that consumers expect to obtain higher utility from search; however, a higher $\underline{\theta}$ also reflects less heterogeneity across houses in the market, which induces consumers to search less. The former effect dominates, thus leading to a positive relationship between V and $\underline{\theta}$. Interestingly, the distribution of θs in the market does not affect the differences across rental prices (as V cancels out when taking the price differences), but it affects prices and profits. In particular, a higher $\underline{\theta}$ leads to lower prices and profits. Intuitively, the higher the expected energy efficiency of the other houses in the market, the lower is the market power of each individual landlord.

The results so far are summarized as follows:

Result 1: *More energy efficient houses are rented at higher prices. An increase in search costs and a reduction in the average energy efficiency in the housing market lead to higher rental prices and higher expected profits. However, since these effects are uniform across houses, the price differences are not affected by search costs nor the average energy efficiency.*

Incentives for information disclosure So far we have applied AVZ's model to our set-up. We now proceed to use it to understand the landlords' incentives to obtain energy certificates (ECs) and the impact this has on the equilibrium rental prices.

Let us now suppose that the tenant who visits a house can observe the house's energy efficiency only if (i) the owner has obtained an EC (*certification*), and only if (ii) the owner has decided to disclose it (*disclosure*).

Assuming that tenants are rational (i.e., through Bayesian updating, they form rational beliefs about the energy efficiency of the houses without an EC)[5] we now analyze the landlords' optimal

[4]For expression (1) to be valid, we require that $u - p(\theta) - V > 0$ for all θ. Using expression (2) for the equilibrium price, this requires $V < \underline{\theta}$. This, together with the condition that V is non-negative, imposes a lower bound on $\underline{\theta} \geq 16s - 1$, or equivalently, an upper bound on s given $\underline{\theta}$.

[5]Frondel et al. (2017)'s model assumes that a fraction of consumers are naive, i.e., they believe that the energy efficiency of the houses without an EC is equal with the population average.

decisions regarding certification and disclosure. We assume that before obtaining the EC, landlords and tenants have the same prior about the energy efficiency of the houses.[6]

Landlords can certify the energy efficiency of their houses by obtaining an EC at a cost c. In order to allow for landlord's heterogeneity, we assume that each landlords' cost c is *i.i.d.* according to a uniform distribution in the unit interval. There are several potential reasons for c to differ across landlords, e.g. they obtain different quotes from different EC providers, and/or their opportunity costs of devoting time to complete the EC paperwork differ.

Having an EC is compulsory but there is imperfect enforcement: landlords are inspected with probability $\rho \in (0,1)$, and if they do not have the EC they have to pay a fine $F \in (0,1)$. Therefore, the value of the expected fine ρF provides a continuous measure of whether the policy is voluntary (if ρF is close to 0 there is no enforcement) or mandatory (if ρF is close to 1 there is full enforcement).[7]

Let $\widehat{\theta}$ be the expected efficiency of the houses without an EC, and suppose that the landlord has decided to obtain an EC (decision C). If the EC reveals that the house's energy efficiency is low $\theta < \widehat{\theta}$, the landlord is better off not showing it and making consumers believe that his house's energy efficiency is equal to the expected level of houses without EC, $\widehat{\theta}$. Accordingly, he discloses his EC only when the it is sufficiently high, $\theta \geq \widehat{\theta}$ (in line with Grossman and Hart (1980) and Jovanovic (1982)). Therefore, the landlord's expected profits from obtaining an EC are

$$E\left[\pi|\, C\right] = \frac{1}{n}\frac{1}{1-\underline{\theta}}\left(\int_{\underline{\theta}}^{\widehat{\theta}} \pi\left(\widehat{\theta}\right) d\theta + \int_{\widehat{\theta}}^{1} \pi\left(\theta\right) d\theta\right), \tag{5}$$

where $1/n$ is the probability that the consumer chooses to visit his house out of the n houses in the market, and $\pi(\theta)$ was defined in equation (3) above.

Instead, if the landlord does not obtain the EC, his expected profits are

$$E\left[\pi|\, NC\right] = \frac{1}{n}\pi\left(\widehat{\theta}\right)\cdot \tag{6}$$

Comparison of (5) and (6) shows, in line with Result 1, that not obtaining the EC has an opportunity cost: the energy efficiency rent premium $E[\pi|\, C] - E[\pi|\, NC]$. Trivially, the landlord can at least obtain the same profits with an EC than without it (as he can always hide it) but obtaining the EC gives him a rent premium if his energy efficiency turns out to be above the average of those houses without the EC. This rent premium is higher the lower $\widehat{\theta}$.

After simple algebra, the rent premium can also be expressed as

$$E\left[\pi|\, C\right] - E\left[\pi|\, NC\right] = \frac{1}{n}\frac{\underline{\theta}}{1-\underline{\theta}}\left(\int_{\underline{\theta}}^{\widehat{\theta}} \pi\left(\widehat{\theta}\right) d\theta + \int_{\widehat{\theta}}^{1} \pi\left(\theta\right) d\theta\right) + \frac{1}{n}\int_{\widehat{\theta}}^{1}\left(\pi\left(\theta\right) - \pi\left(\widehat{\theta}\right)\right) d\theta.$$

Using the expression for $\pi(\theta)$ in equation (3), it can be shown that the two terms in the above

[6] This could be easily relaxed. Allowing landlords to have more precise information, would introduce correlation between not having an EP and having a low efficiency. Hence, the results that are presented below would be reinforced.

[7] The comparison between a voluntary policy versus a mandatory policy with full compliance can thus be assessed in this model by comparing outcomes with $\rho F = 0$ or $\rho F = 1$.

equation are decreasing in V. Hence, landlords capture a higher energy efficiency rent premium the lower the value from search. In turn, since V increases in s , this implies that premia are higher in markets with higher search costs.

Since obtaining the EC implies a cost c, not all landlords decide to obtain one. In particular, landlords have to trade-off the costs c against the gains from obtaining an EC, i.e., the rent premium plus the expected fine ρF which they avoid by obtaining the EC. In particular, only landlords with cost $c < \widehat{c}$ optimally obtain the EC,[8] where

$$\widehat{c} \equiv E\left[\pi | C\right] - E\left[\pi | NC\right] + \rho F.$$

Clearly, $\widehat{c}$ is increasing in the rent premium as well as in the expected fine ρF. Whereas the latter is exogenous, the former is decreasing in $\widehat{\theta}$, i.e., the expected efficiency of the houses without an EC, which is an endogenous object. In particular, $\widehat{\theta}$ is the solution to the following equation:

$$\widehat{\theta} = \frac{\widehat{c}}{1-\underline{\theta}} \int_{\underline{\theta}}^{\widehat{\theta}} \theta d\theta + (1-\widehat{c})\,\widetilde{\theta}. \tag{7}$$

The above equation reflects the expected efficiency of those landlords with either $c < \widehat{c}$ (first term) or $c > \widehat{c}$ (second term). The former optimally decide to obtain the EC but hide it if $\theta < \widehat{\theta}$; hence, the distribution of their θs is truncated at $\widehat{\theta}$. The latter optimally decide not to obtain the EC; hence, their energy efficiency equals the market average. The solution to equation (7), which always exists, is below the average energy efficiency of the houses in the market, $\widetilde{\theta}$, because of the selection bias among the houses whose owners hide the EC.

An increase in the expected fine ρF increases $\widehat{c}$ and therefore reduces the expected efficiency of the houses without EC, $\widehat{\theta}$. This, in turn, increases the rent premium. Hence, the effects of increasing the expected fine go beyond the pure cost related effects: they also play a role through their effect on the rent premium and the resulting increase in certification and disclosure. Also, a shift (in a FOSD sense) of the cost function would increase disclosure; through this effect, it would enlarge the rent premium. This could be achieved by intensifying competition among certifiers.

These results are summarized next:

Result 2: *Only a fraction of landlords find it optimal to obtain an EC; this fraction is increasing in the rent premium and in the expected fine. Among those landlords who obtain an EC, the ones with low efficiency hide them. Due to the increase in the rent premium, an increase in expected fines encourages the disclosure of ECs beyond the pure cost-related effect.*

Empirically, it is not possible to test the predicted negative correlation between the rent premium and the average energy efficiency of the houses without the EC given that the latter is non-observable. However, the fraction of houses in the market which disclose their ECs provides a

[8] The assumption $F < 1$ guarantees that $\widehat{c} < 1$ (given that the rent premium is divided through by n, it is arbitrarily small).

good proxy for $\widehat{\theta}$. In particular, *observed* disclosure of ECs can be expressed as

$$A = \widehat{c}\frac{1-\widehat{\theta}}{1-\underline{\theta}}, \tag{8}$$

as only a fraction $\widehat{c}$ of houses obtain ECs and, among these, only a fraction $(1-\widehat{\theta})/(1-\underline{\theta})$ disclose them. Since both terms in the expression are decreasing in $\widehat{\theta}$, we predict a positive correlation between the *observed* disclosure rates of ECs and the rent premium of the houses with ECs as compared to those without EC. The *observed* disclosure rate A is more informative about the average energy efficiency of the houses without EC in markets where the average energy efficiency (as proxied by $\underline{\theta}$) is higher. An increase in expected fines increases $\widehat{c}$ and thus also strengthens the informativeness of A as a signal for $\widehat{\theta}$.

Result 3: *In markets with higher observed disclosure rates of ECs, the rent premium of the houses with EC is relatively larger. This effect is more pronounced the higher the observed energy efficiency.*

It follows that a boost in disclosure (e.g. triggered by an increase in the expected fines for non-compliance, or by an overall reduction in the costs of obtaining the ECs) would imply a stronger penalty for the houses that hide their ECs. This result in is line with Frondel et al. (2017)'s prediction and empirical findings regarding the effects of moving from a regime of voluntary disclosure to a mandatory one.

In the next sections we explore these testable implications in the context of the Spanish housing rental market.

3. Data

To promote energy efficiency investments, the European Parliament made it mandatory for all member states to disclose the energy performance of all buildings according to Directive 2002/91/EC. The Energy Performance Certificate, which assesses heating systems, ventilation and insulation quality, among others, has a common standard across all member states: houses and buildings are certified with an index that ranges from A to G according to the dwellings' energy efficiency. Spain adhered to this certification procedure in June, 2013 (BOE, 2013). Landlords who do not comply with these standards are subject to fines.[9]

In this paper we use data from the Spanish rental market to empirically test the landlords' motivation to disclose information of the energy efficiency of their houses. We have downloaded cross sectional data of rental advertisements from the main Spanish commercial housing website (Idealista) during April 2016.

[9]The fines for hiding an EC are as follows. Minor infringements receive a fine of 300-600 Euro. These include: publicize the sale or rental of a building without mentioning the energy rating obtained, or failure to display the energy efficiency label in cases resulting mandatory. Serious infringements receive a fine of 601-1000 Euro. These include the sale or rental of a property without giving the buyer or lessee EC registered.

Table I ECs and Green Ideology Across Cities

	Obs.	Cadiz	Jaen	Pamplona	Soria	Huesca	Oviedo	Salamanca	Valladolid
Total	8,009	3,536	614	540	173	470	963	1,186	527
Adoption Rate	19%	13%	18%	47%	14%	17%	23%	20%	23%
AverageLabel	4.35	4.62	4.71	3.30	5.52	4.79	3.75	4.12	4.08
VarianceLabel	3.85	5.02	5.02	0.90	3.08	2.85	3.90	3.17	3.04
Green Vote:									
GreenVote1	0.27%	0.37%	0.17%	0.29%	0.20%	0.21%	0.18%	0.17%	0.18%
GreenVote2	1.91%	2.88%	1.59%	1.07%	0.81%	1.16%	1.30%	0.95%	0.92%
GreenVote3	25.19%	32.13%	16.33%	29.18%	19.41%	22.30%	21.55%	15.32%	18.19%

The advertisements available on Idealista provide us information about the dwellings' rental price, their location, their advertisement type, their characteristics, and their EC ratings (if they have one). According to the theoretical model presented in the previous section, the disclosure rate of ECs and the distribution of efficiency of the houses in a local market affect the rent premium. To obtain the variation of these determinants, we focus attention on eight relatively small Spanish cities with an average of 100,000 inhabitants each. These cities are treated as eight separate markets (Figure 1). Our sample consists of 8,009 ads that are spread across these cities.

The disclosure rate of ECs in each city is computed as the percentage of houses in the city that display the EC information online. To calculate the mean and variance of EC ratings within each city, we assign numbers from 7 to 1 to the ratings A to G, with higher values indicating more energy efficient houses. The summary statistics of ECs are shown in Table I. With only 1,506 out of 8,009 ads including EC information, the mean disclosure rate is 19%.[10] Pamplona has the highest disclosure rate, 47%, and Cádiz has the lowest, 13%. The average EC rating (denoted as $AverageLabel$) is 4.35, i.e., dwellings with a C or D label on average. According to our data, the variance of ECs (denoted as $VarianceLabel$) ranges from 3.30 to 5.52. The mean and variance help us characterize the distribution of ECs in each local market.

Furthermore, we construct the variables $GreenVote$ to capture the green ideological heterogeneity of the homeowners in each city.[11] We measure these variables as the fraction of votes for green parties in Spain's 2016 General Election. In $GreenVote1$, only "Recortes Cero-Grupo Verde" is treated as green party. In $GreenVote2$, both "Recortes Cero-Grupo Verde" and "Pacma" are green. Last, in $GreenVote3$, "Recortes Cero-Grupo Verde", "Pacma" and "Unidos Podemos" are all treated as green parties.[12] As it will be later explained, we will use these variables as determinants of the decision to obtain and disclose energy certificates.

Table II provides descriptive statistics of the ads of the labeled and non-labeled samples. Rel-

[10]This number is in line with those reported in other studies. In Holland, the adoption rate is even lower 17% (Brounen and Kok, 2011).

[11]See also Brounen and Kok (2011) and Dressler and Cornago (2017), who use the same approach.

[12]Recortes Cero-Grupo Verde is the Spanish green party. Pacma is a party that defends animals' rights. And Unidos Podemos is a left-wing party.

Figure 1. City-level Rental Markets

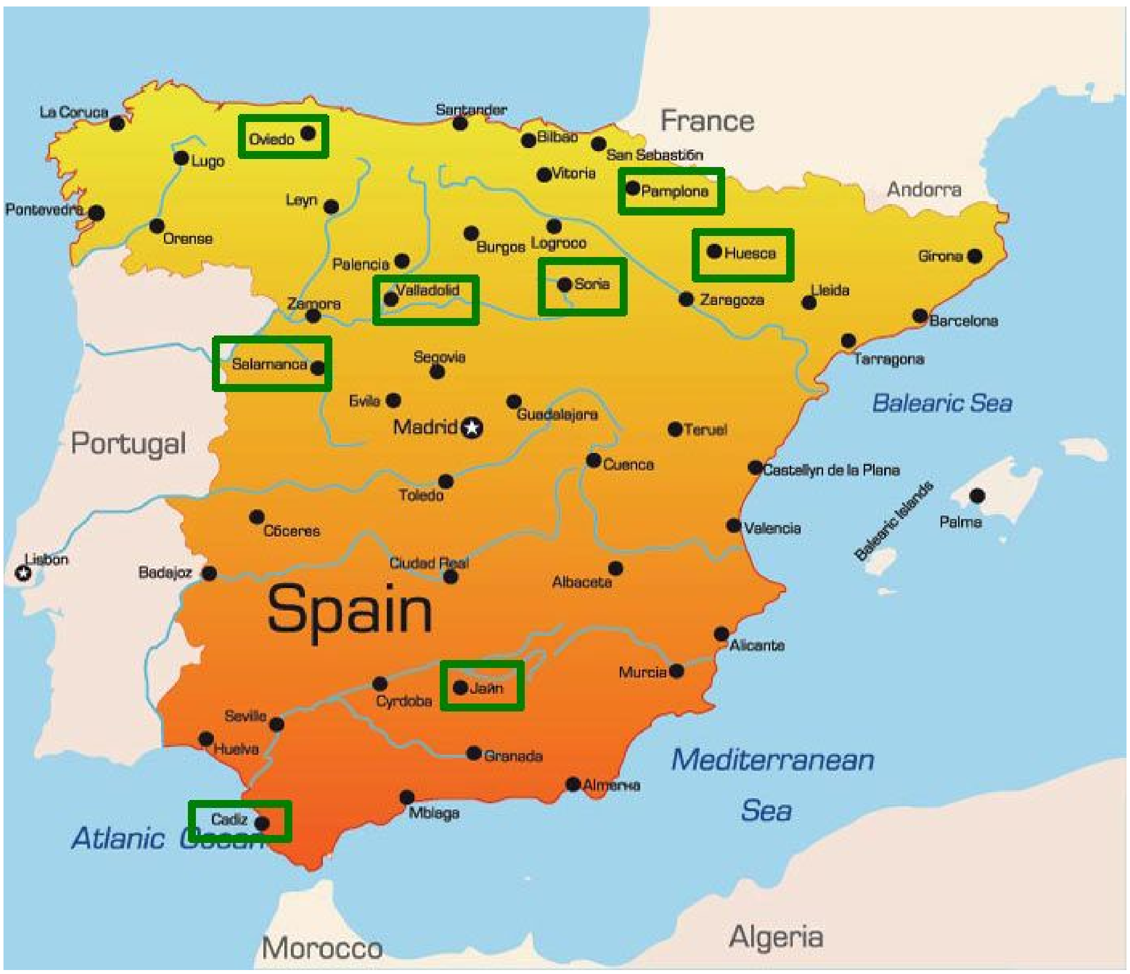

Table II Descriptive Statistics: Houses

	All Dwellings		Labeled Dwellings		Non-labeled Dwellings	
	Mean	St.Dev	Mean	St.Dev	Mean	St.Dev
Adoption rate	0.19	0.09				
Price (Euro/square meter)	6.81	4.69	6.83	4.47	6.80	4.73
Size (square meters)	104.93	137.03	98.36	61.14	106.46	149.16
Bedrooms	2.64	1.20	2.62	1.22	2.65	1.19
WC	1.60	0.78	1.57	0.71	1.61	0.79
Storeroom	0.21	0.40	0.23	0.42	0.20	0.40
Fitted wardrobe	0.57	0.50	0.58	0.49	0.56	0.50
Parking	0.33	0.47	0.31	0.46	0.33	0.47
Lift	0.59	0.49	0.71	0.45	0.56	0.50
Detached/Semi-Detached	0.09	0.28	0.05	0.22	0.10	0.30
Second hand/good condition	0.96	0.18	0.98	0.15	0.96	0.19
Fully equipped kitchen and unfurnished houses	0.09	0.29	0.10	0.30	0.09	0.28
Fully furnished and equipped	0.59	0.49	0.64	0.4	0.57	0.49
Non equipped kitchen and unfurnished house	0.04	0.20	0.04	0.20	0.04	0.20
Advertisement Type						
Professional	0.48	0.50	0.44	0.50	0.49	0.50

Table III Descriptive Statistics: ECs

	Total	A	B	C	D	E	F	G	Not available
Sample Size	1506	315	76	123	233	386	70	146	157
Percentage		20.91%	5.04%	8.16%	15.47%	25.63%	4.64%	10.82%	10.42%

ative to the unlabeled dwellings, the rental prices of the labeled dwellings are slightly higher on average. Also, the labeled houses are smaller in size and in a better condition on average relative to those houses without certificates. The percentage of houses needing renovation is higher among the unlabeled houses.

As shown in Table III, one fifth of the 1,506 houses with EC information are very energy efficient (*A* label), while 10.82% of them are very energy inefficient (*G* label). In our empirical analysis, we divide labels into three groups: most efficient group (A or B), group with average energy efficiency (C, D or E) and inefficient group (F or G).

4. Empirical Analysis

A. *Is there an energy efficiency premium?*

According to Result 1, we expect those houses certified as efficient to be rented at higher prices. To measure the energy efficiency premium in the Spanish rental market, we use the standard valuation framework. In a hedonic model, a product is assumed to be decomposed into its attributes, with the price of a product being a function of such attributes (Rosen, 1974). Our basic hedonic regression takes the following form:

$$log(price/m_i^2) = \beta_0 + \beta_1 Label_i + \beta_k X_i + \alpha_n + \epsilon_i \tag{9}$$

where the dependent variable $log(price/m^2)$ is the logarithm of the rental price per square meter of dwelling i. $Label_i$ includes two dummy variables, which capture the houses' energy efficiency levels. We divide them into three groups: the dummy $A + B$ equals one for houses with the most efficient labels A and B, it equals zero otherwise; the dummy $C + D + E$ equals one for houses labeled as C, D, or E. The estimated coefficients for $A + B$ and $C + D + E$ thus measure the energy efficieny premium as compared to the most inefficient houses, labeled as E or F. According to our model, we expect a positive rent premium for those houses that are more energy efficient, indicating that those coefficients must be ranked as $A + B > C + D + E > 0$. X_i is a vector of the dwelling's characteristics, including size, number of bedrooms, the house condition, etc. Last, we include α_n as city-fixed effects to control for potential heterogeneity across local markets. The error term is denoted ϵ_i.

However, the disclosure of ECs is likely not random, as the theory section showed. Owners of more efficient houses have greater incentives to obtain and disclose their ECs, and houses which are in better condition tend to be more energy efficient. This may introduce selection bias as we only observe the efficiency labels of a non-random subset of houses. To account for this, we use a Heckman two-step method (Heckman, 1979). Firstly, we use a probit model to estimate the probability of obtaining and disclosing ECs using the full sample of houses:

$$\begin{aligned} Pr(EC_i) = &\beta_0 + \gamma GreenVote_n + \sigma AdoptionRate_n + \rho Income_n + \\ &\eta AverageLabel_n + \delta VarianceLabel_n + \beta_k X_i + \epsilon_i \end{aligned} \tag{10}$$

where EC_i is a dummy variable that takes the value one if the house displays an EC, and zero otherwise. While we do not observe the energy efficiency of the unlabeled houses, we can infer some information about it from the house's characteristics X_i.

Furthermore, we also include other variables that affect the incentives to obtain and disclose the ECs. As suggested by our theory model, the rent for unlabeled houses is negatively related to the adoption rate of ECs in the local market. Thus, landlords may take into consideration the adoption rate (captured by *AdoptionRate*) when deciding whether to obtain and disclose their ECs. Also, the variables $AverageLabel_n$ and $VarianceLabel_n$, which measure the mean and variance of ECs in the city n where the house is located, might affect the incentives to obtain and disclose the ECs through the effects on consumers' value from searching and ultimately on prices. The same applies to $Income_n$, which stands for the average income per capita in city n. We also include the share of votes for the green parties in the city n where the house is located ($GreenVote$) as an instrumental variable. The premise is that in cities with a higher environmental awareness (as reflected in the share of green votes), landlords are more likely to obey to the energy efficiency regulation. Under the assumption that the share of green votes is not directly related to the rental price, the exogenous determinant of $GreenVote$ could help us correctly identify the potential selection bias. Last, due to potential collinearity, we eliminate the city-fixed effects from the specification under the implicit assumption that the city-fixed effects affecting the incentives to disclose ECs are fully captured by these variables.

Table IV presents the results of the logit estimation with three different measurements of $GreenVote$. The three specifications report similar results, showing that the probability of obtaining and displaying the EC increases with environmental awareness, as reflected by $GreenVote$. The estimated coefficients on the $GreenVote$ variables are larger under the most restrictive definition ($GreenVote1$), while the estimates of the other variables remain fairly unchanged across the three specifications.

Consistent with our theoretical predictions, in cities with higher adoption rates, landlords are significantly more likely to obtain and disclose their ECs. According to our theoretical model, in local markets in which consumers' expected value from searching is higher (which in turn is positively correlated with the mean and variance of the ratings), the rent efficiency premium shrinks down, leading landlords to be more reluctant to obtain and disclose their ECs. Consistent with this, the estimates on the mean and variance of the ECs in our logit model (η and δ) are negative across the three specifications. The average income level is negatively related to the probability of obtaining ECs, but the effect is non-significant.

As expected, houses in good condition are more likely to disclose the EC information; this effect is significant at the 10% level in all three specifications. Also, those dwellings with lifts and storerooms are significantly more likely to be labeled. In contrast, the size of the dwellings, number of WCs and bedrooms do not seem to be correlated with the incentives to adopt and disclose EC information. The advertisement type has a distinct influence on the likelihood of disclosing the EC: relative to private ads, those provided by professional agents are less likely to have it and disclose it. One potential explanation is that the opportunity cost of those landlords that rely on professional agents to rent their houses is higher, and so their likelihood of obtaining the EC is lower.

In sum, the likelihood of obtaining and disclosing an EC increases with $GreenVote$, i.e., the measure of environmental ideology, and the adoption rate in each market. As there are no significant differences among the three specifications, we only report the estimated results with $GreenVote2$ in what follows.

With the estimated probit, we construct consistent estimates of the inverse Mills ratio $\hat{\lambda}$. The inverse Mills ratio is added as an instrumental variable in the basic hedonic model to deal with the self-selection issue.

$$\begin{aligned} log(price/m^2)_i =& \beta_0 + \beta_1 Label_i + \beta_k X_i + \tau\hat{\lambda}_i + \rho Income_n + \\ & \eta AverageLabel_n + \delta VarianceLabel_n + \epsilon_i \end{aligned} \tag{11}$$

Column (1) in Table V reports the estimated results for the basic hedonic model. In Column (2), we add the inverse Mills ratio to control for the potential selection bias. Based on the 1,348 labeled dwellings in the sample, our model explains about 37% of the natural logarithm of the rental price per square meter, or 39% when we control for the potential selection bias.

Compared with those houses labeled as E or G, the estimated energy efficiency rent premium associated with the most efficient labels (A or B) is 7%, which is significant at the 10% level. In turn, the energy efficiency premium for those houses labeled as C, D or E is 5%, which is also significant at 10% level. The magnitude is similar to those found in other countries (see the empirical evidence reviewed by Ramos et al. (2015)).

Controlling for the potential selection bias has little influence on the estimated energy efficiency rent premium. As shown in column (2), the coefficient on the inverse Mills ratio $\hat{\lambda}$ is positive, implying a insignificant positive correlation between the error term in the selection equation and the primary equation in the subsample with labels. The unobserved factors, which make landlords more likely to obtain and disclose their ECs, tend to have a positive, although not significant, impact on the rent for the labeled houses.

As for the houses' characteristics, smaller dwellings tend to have higher rents per square meter. Having an additional WC or being detached are associated with a significantly higher rent. Additional bedrooms and parking areas have a minor effect on the rental price, and the rent per square meter is significantly higher for those houses with fitted wardrobes and lift. Last, tenants are willing to pay more for houses in good condition, although the effect is not significant. And those houses which are fully furnished or equipped are rent at significant higher prices. Also, the rent tends to be higher in a city with higher average income.

B. *How do rental prices depend on the disclosure rate of ECs?*

Based on our theoretical model, tenants are willing to pay a higher rent for the unlabeled houses the higher their expected energy efficiency $\hat{\theta}$. The negative relationship between the observed disclosure rate and $\hat{\theta}$ predicts that the rental price of the unlabeled houses is relatively lower in markets with higher observed disclosure rates, as captured in equation (8). We now test this prediction empirically.

In order to deal with the selection bias, we use Heckman's two-step method, similarly to what we did before. In the first stage, we estimate the probability of not showing the EC with a probit

Table IV The Determinants of EC Adoption

	(1)	(2)	(3)
City Characteristics			
Greenvote1	45.06		
	(36.12)		
Greenvote2		6.10	
		(5.33)	
Greenvote3			0.72
			(0.27)
AverageLabel	-0.17*	-0.17*	-0.18*
	(0.08)	(0.08)	(0.09)
VarianceLabel	-0.01	-0.04	-0.01
	(0.03)	(0.04)	(0.03)
Income	-0.05	-0.04	-0.06
	(0.03)	(0.03)	(0.04)
Adoption Rate	3.24***	3.21***	3.33***
	(0.64)	(0.63)	(0.65)
House Characteristics			
Dwelling Size (log)	-0.05	-0.05	-0.05
	(0.07)	(0.07)	(0.07)
Bedrooms	-0.03	-0.03	-0.03
	(0.02)	(0.02)	(0.02)
WC	0.01	0.01	0.01
	(0.03)	(0.03)	(0.03)
Storeroom	0.08*	0.08*	0.08*
	(0.04)	(0.04)	(0.04)
Fitted Wardrobe	0.06	0.06	0.06
	(0.04)	(0.04)	(0.04)
Parking	0.003	0.004	-0.02
	(0.04)	(0.04)	(0.04)
Lift	0.20***	0.20***	0.20***
	(0.04)	(0.04)	(0.04)
Detached/Semi-detached	-0.07	-0.07	-0.07
	(0.08)	(0.08)	(0.08)
Second Hand/Good Condition	0.17*	0.16*	0.17*
	(0.10)	(0.10)	(0.10)
Fully furnished/equipped	0.00	0.00	0.00
	(0.04)	(0.04)	(0.04)
Advertisement Type			
Professional	-0.35***	-0.35***	-0.35***
	(0.04)	(0.04)	(0.04)
Constant	0.44	0.41	0.76
	(0.96)	(0.99)	(1.26)
Sample Size	8001	8001	8001
Pseudo R^2	0.06	0.06	0.06

Table V Energy Certificates and Rental Prices

	(1)	(2)	(3)	(4)
EC				
A or B	0.07*	0.07*		
	(0.04)	(0.04)		
C, D or E	0.05*	0.05*		
	(0.03)	(0.03)		
City Characteristics				
Adoption Rate			-2.01***	-6.17***
			(0.16	(0.36)
AverageLabel	0.09***	0.05	-0.003	0.03*
	(0.03)	(0.04)	(0.02)	(0.02)
VarianceLabel	-0.01	-0.03	-0.07***	-0.07***
	(0.01)	(0.02)	(0.01)	(0.01)
Income	0.07***	0.08***	0.12***	0.12***
	(0.01)	(0.01)	(0.005)	(0.005)
House Characteristics				
Dwelling Size (log)	-0.61***	-0.61***	-0.61***	-0.56***
	(0.06)	(0.06)	(0.04)	(0.03)
Bedrooms	0.01	0.01	0.01	0.04***
	(0.02)	(0.02)	(0.01)	
WC	0.15***	0.15***	0.17***	0.15***
	(0.03)	(0.03)	(0.01)	(0.01)
Storeroom	-0.05*	-0.04	-0.04***	-0.12***
	(0.03)	(0.03)	(0.01)	(0.01)
Fitted Wardrobe	0.10***	0.10***	0.07***	0.006
	(0.02)	(0.02)	(0.01)	(0.12)
Parking	0.05*	0.04*	0.07***	0.06***
	(0.03)	(0.03)	(0.01)	(0.01)
Lift	0.11***	0.13***	0.10***	-0.07***
	(0.03)	(0.03)	(0.01)	(0.02)
Detached/Semi-detached	0.55***	0.54***	0.27***	0.32***
	(0.10)	(0.10)	(0.03)	(0.03)
Second Hand/Good Condition	0.03	0.05	-0.03	-0.18***
	(0.06)	(0.06)	(0.03)	(0.03)
Fully furnished/equipped	0.08***	0.08***	-0.02	-0.02*
	(0.02)	(0.02)	(0.01)	(0.01)
Advertisement Type				
Professional	0.09***	0.04	0.08***	0.41***
	(0.02)	(0.04)	(0.08)	(0.03)
Selection $\hat{\lambda}$		0.17		2.69***
		(0.14)		(0.20)
Constant	1.74***	1.60***	1.62***	1.37***
	(0.40)	(0.43)	(0.19)	(0.19)
Sample Size	1348	1348	6496	6496
R^2	0.37	0.39	0.39	0.39

model over the full sample:

$$
\begin{aligned}
Pr(1 - EC_i) = &\beta_0 + \gamma GreenVote_n + \sigma AdoptionRate_n + \rho Income_n + \\
&\eta AverageLabel_n + \delta VarianceLabel_n + \beta_k X_i + \epsilon_i
\end{aligned}
\tag{12}
$$

In the second stage, we use the sample of unlabeled houses. The inverse Mills ratio $\hat{\lambda}$ and its interaction with the disclosure rate are added to deal with the potential selection bias:

$$
\begin{aligned}
log(price/m^2)_i = &\beta_0 + \beta_1 AdoptionRate + \beta_k X_i + \tau \hat{\lambda}_i + \rho Income_n \\
&+ \eta AverageLabel_n + \delta VarianceLabel_n + \epsilon_i
\end{aligned}
\tag{13}
$$

Columns (3) and (4) of Table V report the results of this estimation without controlling and controlling for the potential selection bias, respectively. Adding the inverse Mills ratio, a 1% higher disclosure rate is associated with a reduction in the rental price of 6.1%. The magnitude of this effect is much smaller without considering the potential selection bias. In line with our model, in markets with higher disclosure rates tenants are willing to pay less for the unlabeled houses as they expect their energy efficiency to be lower.

The dwellings' characteristics have similar impacts on the rental price, as in the previous specifications. The fact that the second hand/good condition variable now takes a different sign could be explained by the heterogeneity in landlords' subjectivity when defining what good condition means. Consumers are willing to pay more for those apartments with parking area and lifts as well as for houses with more WCs. And the detached houses are associated with significant higher rent. Additionally, the unobserved factors (as captured by $\hat{\lambda}$), which make the landlords more reluctant to disclose ECs, are significantly positively related to the rental price.

In terms of market characteristics, the second moment of the EC ratings shows the sign predicted by the model. As explained in section 2, the value of search increases with the heterogeneity across houses. The negative relationship between the price and the value of search implies that the rent decreases with the variance of the energy efficiency rating. Additionally, rental prices increase with the average income of the city, as expected.

5. Conclusions

Energy efficiency is increasingly considered an important contributor to reducing carbon emissions. Although studies provide evidence that investments in energy efficiency provide net-positive gains, there is broad evidence pointing at an energy efficiency gap in practice. One of the major reasons for this gap is underinvestment due to the presence of imperfect information. This paper focuses on the impact of asymmetric information regarding energy efficiency and applies it to understanding rent premia and disclosure rates of energy certificates in the Spanish residential rental market. We construct a model of price formation in the rental market that combines search frictions and asymmetric information about houses' energy efficiency. The model delivers three types of predictions. First, more energy efficient houses are rented at higher prices, i.e., there is an efficiency rent premium. An increase in search costs and a reduction in the average energy efficiency increases rental prices and expected profits. However, since these effects are uniform across houses, the price differences are not affected by search costs or the average energy efficiency in the housing market. Second, only a fraction of landlords find it optimal to obtain an EC; this fraction is increasing in the rent premium and in the expected fine. Among those landlords who obtain an EC, the ones with low efficiency prefer not to disclose them. An increase in expected fines increases the rent premium, and hence it encourages the disclosure of ECs beyond the pure cost-related effect. Last, in markets with higher observed disclosure rates of ECs, unlabeled houses face a higher rent penalty.

We construct a new dataset of the Spanish rental market and use it to test the theoretical predictions. In contrast to other papers, we control for the heterogeneous effects of energy efficiency on house characteristics, as well as for the mean and variance of the ECs as these affect the incentives to search in the local market. We find a higher rent premium than in studies conducted in other European local markets. We also find evidence of an efficiency penalty as the unlabeled houses are rented at lower prices as compared to the efficient ones. Such a penalty is lower the greater the disclosure rates of ECs in each local market. This implies that landlords face stronger incentives to obtain and disclose their ECs in markets in which disclosure rates are higher.

In sum, these results suggest important policy implications regarding the promotion of investments in energy efficiency in the rental market. In particular, a push in the disclosure rate (e.g. through higher fines for noncompliance), would increase disclosure, which would in turn reduce the rent of the unlabeled houses, further encouraging landlords to disclose their ECs. Hence, if regulators could choose to devote their resources to enforce the EC policy, they should be more stringent in the first phase, when disclosure rates are low and hence the incentives for information provision are still weak.

References

Allcott, Hunt, and Michael Greenstone, 2012, Is there an energy efficiency gap?, *Journal of Economic Perspectives* 26, 3–28.

Armstrong, Mark, John Vickers, and Jidong Zhou, 2009, Prominence and consumer search, *The RAND Journal of Economics* 40, 209–233.

Brounen, Dirk, and Nils Kok, 2011, On the economics of energy labels in the housing market, *Journal of Environmental Economics and Management* 62, 166–179.

Burlig, Fiona, Christopher Knittel, David Rapson, Mar Reguant, and Catherine Wolfram, 2017, Machine learning from schools about energy efficiency, Technical report, National Bureau of Economic Research.

Dressler, Luisa, and Elisabetta Cornago, 2017, The rent impact of disclosing energy performance certificates: Energy efficiency and information effects, *ECARES Working Papers* .

Eichholtz, Piet, Nils Kok, and John M Quigley, 2010, Doing well by doing good? green office buildings, *American Economic Review* 100, 2492–2509.

Fowlie, Meredith, Michael Greenstone, and Catherine Wolfram, 2018, Do energy efficiency investments deliver? evidence from the weatherization assistance program, *The Quarterly Journal of Economics* 133, 1597–1644.

Frondel, Manuel, Andreas Gerster, and Colin Vance, 2017, The power of mandatory quality disclosure: Evidence from the german housing market, *Annual Conference 2016(Augsburg): Demographic Change 145815, German Economic Association* .

Fuerst, Franz, and Georgia Warren-Myers, 2018, Does voluntary disclosure create a green lemon problem? energy-efficiency ratings and house prices, *Energy Economics* 74, 1–12.

Gerarden, Todd D, Richard G Newell, and Robert N Stavins, 2017, Assessing the energy-efficiency gap, *Journal of Economic Literature* 55, 1486–1525.

Grossman, Sanford J, and Oliver D Hart, 1980, Takeover bids, the free-rider problem, and the theory of the corporation, *The Bell Journal of Economics* 42–64.

Heckman, James J, 1979, Sample selection bias as a specification error, *Econometrica* 47, 153–161.

Jovanovic, Boyan, 1982, Selection and the evolution of industry, *Econometrica: Journal of the Econometric Society* 649–670.

Kok, Nils, Marquise McGraw, and John M Quigley, 2011, The diffusion of energy efficiency in building, *American Economic Review* 101, 77–82.

Milgrom, Paul R, 1981, Good news and bad news: Representation theorems and applications, *The Bell Journal of Economics* 380–391.

Myers, Erica, 2015, Asymmetric information in residential rental markets: Implications for the energy efficiency gap, *Energy Institute at Haas Working Paper* 246.

Ramos, Ana, Alberto Gago, Xavier Labandeira, and Pedro Linares, 2015, The role of information for energy efficiency in the residential sector, *Energy Economics* 52, S17–S29.

Rosen, Sherwin, 1974, Hedonic prices and implicit markets: product differentiation in pure competition, *Journal of Political Economy* 82, 34–55.

Wolinsky, Asher, 1986, True monopolistic competition as a result of imperfect information, *The Quarterly Journal of Economics* 101, 493–511.

Appendix

Figure 2. Energy Performance Certificate