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THE CAPITALIZATION OF ENERGY LABELS INTO HOUSE PRICES. EVIDENCE FROM ITALY

by Michele Loberto, Alessandro Mistretta and Matteo Spuri *

Abstract

Mitigating the negative impact of climate change implies a drastic reduction in greenhouse gas emissions: moving towards the net-zero target requires, among other things, a dramatic improvement in the energy efficiency of residential buildings, which account for 12.5 per cent of greenhouse gas emissions in Italy. This paper estimates the extent to which energy efficiency labels are capitalized into house prices. We find that the most energy-efficient houses sell at a 25 per cent premium over the least efficient ones. Our contribution is relevant for two reasons. First, we provide granular estimates of the impact of energy labels on house prices in Italy and show that the energy efficiency premium is significantly heterogeneous across provinces due to differences in climate conditions and regulatory frameworks. Second, energy labels play a key role and are used as a benchmark for several policies, and the heterogeneity in the energy efficiency premium may call for more targeted public policies that promote investment in energy efficiency.

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Contents

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1 Introduction[1]

Climate change and the associated increase in temperatures is a serious threat to current living standards. Mitigating the negative impact of climate change implies a drastic reduction in the emissions of greenhouse gases into the atmosphere toward a zero-emission target. However, this transition is challenging and requires a comprehensive strategy affecting many sectors of the economy. Among the potential interventions, many countries in Europe recognize that moving toward the zero-emission target would require dramatically improving the energy efficiency of buildings. In the European Union, for example, residential buildings are responsible for about 9% of total greenhouse gas emissions (European Commission, 2021).[2]

In Italy, houses account for 12.5% of greenhouse emissions (ISPRA, 2023), and are quite old on average.[3] This is a serious obstacle to the full decarbonization of households' energy use and it is also a thorny social issue, and the Italian government has been providing subsidies to improve the carbon and energy footprint of dwellings for several years (*Ecobonus* and *Superbonus 110*). Yet, a crucial unanswered question is how much energy efficiency is capitalized into house prices. This question is pivotal for several reasons. First, based on an asset-pricing framework, following an investment in energy efficiency, the price of a house should increase because of the lower future energy expenditure. Therefore, house prices may reveal the future benefits of investment in energy efficiency. Second, knowing the private benefit of energy efficiency investments is critical to design optimal public policies to incentivize the retrofitting of the housing stock. Third, houses are the largest component of households' wealth and a primary source of collateral backing a large share of bank loans. Therefore, evaluating the impact of energy efficiency on housing market prices holds significant implications for financial stability.[4]

[1] We are extremely grateful to Immobiliare.it for providing the data and Andrea Luciani for his assistance. We thank Paolo Angelini, Guido De Blasio, Silvia Fabiani, Ivan Faiella, Alberto Felettigh, Patrizio Pagano and Francesco Zollino for their comments. We thank Carlo Romeo for an insightful discussion about the Italian regulation on buildings' energy efficiency. The opinions expressed are those of the authors and do not necessarily reflect the views of the Bank of Italy or the Eurosystem. All remaining errors are our own.

[2] In 2021, the European Commission proposed an ambitious plan for reducing buildings-related emissions by 60% by 2030. A new regulation to achieve this target is currently under discussion.

[3] About 75% of the existing housing stock was constructed before 1980. About 30% of the residential buildings were constructed between 1946 and 1970, when the quality of construction was poor due to the need to rebuild quickly the stock of houses destroyed during WW2 and to accommodate the heavy migration flow from the rural areas to the cities.

[4] Such assessments can enhance the collateral value of properties, offering protection not only against rising energy costs but also against the upfront expenses of meeting future stringent environmental regulations, thereby mitigating

This paper reports evidence on the extent of the capitalization of energy efficiency into house prices in Italy. We exploit a large dataset of listings from Immobiliare.it, the largest online portal for house sales in Italy, including information on the energy label of the homes. By combining this information with a rich set of variables about housing characteristics, location, and listing prices, we estimate the contribution of energy labels to house prices. As we will discuss below, energy labels suffer severe limitations in terms of comparability between locations.[5] Yet, this information is salient for market players and is the reference target for accessing some government grants. Because of this crucial role, energy labels are prominent in the advertisements, while very rarely advertisements include a valuation of energy efficiency more precise than the simple energy label.

As the Italian housing stock is old and not refurbished, most houses feature a disappointing energy performance. According to IEA (2023), residential buildings' energy demand is almost twice that of service sector buildings in Italy and accounts for 68% of buildings' total energy final consumption in 2021. In the last 20 years, natural gas was the main source of energy in buildings (51% in 2021), while electricity was less relevant (about 27% in 2021).[6]

Looking at home listings, the market supply of energy-efficient houses is limited and expensive. In 2022, about 10% of homes for sale on Immobiliare.it had energy labels from *A1* to *A4* – the most energy-efficient classes – while about 65% had energy labels equal to F or G, corresponding to the less energy-efficient homes; on average, in 2022, the (unconditional) price per square meter of a house with a label from *A1* to *A4* was higher by about 40% than a house with label F or G.

We perform a regression analysis to identify the specific contribution of energy labels to house prices and find that it is statically significant and economically meaningful. Ceteris paribus, the listing price of a house increases with the energy label, and for homes with energy label A the price is 25% higher than the worst energy-performing houses. However, these are average results at the national level that hide strong heterogeneity at the territorial level. For example, considering the distribution across provinces of the price premium for houses with energy label A, the 5^{th} percentile is 7% and the 95^{th} percentile is 45%.

transition risks (Bell et al., 2023).

[5]As described in Section 2, energy labels are calculated by relating a house-specific energy efficiency measure to benchmark values that vary across municipalities. In addition, technical regulations are not uniform across regions. Some regions, such as Trentino Alto Adige and Lombardia, have significantly different regulations. As a result, energy labels are not easily comparable across regions.

[6]In this context, buildings are expected to contribute around 60% of the annual final energy savings target to 2030 and the strategy sets out the technical, financial and regulatory measures to achieve it (MiTE, 2021).

The large dispersion in the extent of the capitalization of energy labels can be partly explained by two factors. First, as we mentioned earlier and shall discuss in detail in Section 2, energy labels suffer limitations in terms of comparability between locations. Second, Italy features significant heterogeneity in climate conditions across the country: Italian municipalities are classified into climate zones, and the average price premium for label-A homes goes from 12% in the warmest zones to 37% in the coldest zones. Such difference is likely to be driven by the fact that retrofitting costs for enhancing energy efficiency are higher in the coldest zones.[7] However, we also find that provinces with similar climate conditions may feature significantly different capitalization levels.

Even with these caveats, our results have relevant implications for designing incentive programs for housing retrofitting or in the debate about the implications of new European regulations penalizing energy-inefficient homes.[8] First, in Italy subsidy programs to incentivize energy efficiency of the housing stock need only cover a portion of overall retrofitting costs: since house prices incorporate the benefits of energy efficiency work, homeowners receive an immediate benefit from the investment that need not be subsidized by the government.[9] Moreover, if the housing market already penalizes energy-inefficient homes, wealthy households already have a private incentive to invest in their houses. Therefore, focusing subsidies on poor or liquidity-constrained households could be more cost-efficient. Second, the heterogeneity of the price premium for more energy-efficient homes implies that homogeneous policies at the national level are not the best tool to stimulate energy efficiency in the housing stock. Instead, differentiated subsidies on a regional or provincial basis would be more effective, in particular concerning the costs of these policies for the public budget. Furthermore, the option to differentiate the subsidy based on income should be considered to ensure a "just transition" that effectively greens the economy while promoting fairness and inclusivity for all stakeholders.

Literature. In the literature exploring the effects of climate change on the real estate market, we can distinguish between works examining the consequences of physical risk (see, among others, Loberto and Spuri (2023); Benetton et al. (2022)) and those focusing on the study of transition

[7]Unfortunately, we do not have estimates of retrofitting costs across the country, and we cannot formally test this hypothesis.

[8]This paper focuses on the private benefit for homeowners of buildings energy efficiency, abstracting from the social benefits in terms of lower emissions.

[9]In addition to being linked to energy savings, the benefit is also associated with enhanced comfort in the dwellings; European legislation recognizes different levels of comfort also based on the characteristics of the residents living within the houses, such as older people or care and support needs (Faiella et al., 2017).

risk. Notably, among the latter, the studies investigating the influence of the Energy Performance Certificate (EPC) on real estate prices hold significant relevance. These studies consistently found that green buildings command a premium compared to non-labeled homes, highlighting the positive price effects of mandatory and voluntary EPC labels (Eichholtz et al., 2013; Kahn and Kok, 2014; Fuerst et al., 2015; Aydin et al., 2020). Other studies have demonstrated a positive impact of energy efficiency for rental markets, underlining the value that tenants place on energy-efficient properties.

In contrast to most papers, a different strand of the literature reported limited or negligible effects of energy labels on dwelling prices (Murphy, 2014; Fregonara et al., 2017; Olaussen et al., 2019; Myers, 2019). The positive price effects are primarily driven by the energy performance of the dwellings rather than the stigma associated with the energy label itself (Olaussen et al., 2017). Recent research has also examined the geographical heterogeneity of EPC effects. It reveals that the impact of EPCs is weaker in large cities compared to other urban areas, while rural regions exhibit a stronger effect (Taruttis and Weber, 2022).

Furthermore, some studies have investigated the relationship between subsidized investments in energy efficiency and subsequent capitalization. These papers have found that upfront investment costs are approximately double the actual energy savings (Fowlie et al., 2018), as the engineering models predicting higher expected savings are flawed. Christensen et al. (2022) show that targeting the public subsidies to homes with specific characteristics improves the effectiveness of investment in energy efficiency dramatically.

Despite the relevance of these studies, it is essential to note that many of them rely on case studies and small sample sizes, limiting their external validity. The present work contributes to this body of literature using a rich dataset to provide further insights into the topic.

Overview. The rest of the paper is organized as follows. Section 2 discusses the regulatory framework. Section 3 describes the data. Section 4 presents the empirical results. Section 5 discusses the results and concludes.

2 The legislation on the energy performance of buildings

Italy has adopted national legislation on buildings' energy efficiency since 2005. The first regulatory framework was introduced to implement the Energy Performance of Buildings Directive (EPBD) approved by the European Union in 2002. A key issue in the 2000s was that the national legislation only established a general framework, and regional authorities had significant autonomy in implementing the European directive.[10] As a result, the Energy Performance Certification (EPC; *Attestato certificazione energetica*, ACE in Italian) system exhibited significant heterogeneity in its implementation across regions. As we will discuss later, the subsequent legislation has only partly solved this issue.

An important provision of the national regulation was the mandatory disclosure of the EPC for home sales and leases. From 2011, this obligation consisted of verbal communication of the house's Energy Performance Certification (EPC) from the seller (landlord) to the buyer (tenant).[11] In 2012, it became mandatory to attach the EPC to the sale or lease contract and for real estate listings to include the EPC.

Following the adoption of the "EPBD recast" in 2010, the second version of the EPBD,[12] Italy made substantial changes to its general framework for the EPC, transitioning from ACE to APE (*Attestato prestazione energetica*). Since then, the significant milestone has been the

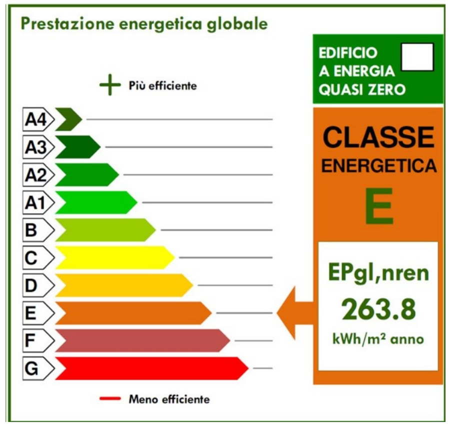
[10] According to the Italian constitutional setup, legislation powers on buildings regulations are shared between the national and the regional governments.

[11] The initial version of the regulation (2005) implied a requirement to include the EPC certificate in the contract. However, this obligation was abolished between 2008 and 2011, and since then, it has transformed into a simple communication process.

[12] In 2021, as part of the "fit for 55" program, the European Commission introduced a proposal to amend the EPBD [COM (2021) 802] with the goal of achieving a zero-emissions target for the stock of buildings by 2050. This proposal lays out various conditions, including financial aspects, aimed at improving the efficiency of real estate throughout Europe. The proposal encompasses several key innovations: (i) The establishment of Zero-Energy Buildings (ZEB) as the new standard for new constructions, surpassing the previous concept of nZEB; (ii) The introduction of national renovation plans to promote building upgrades and energy-efficient improvements; (iii) The definition of minimum requirements at the European level, ensuring a unified approach towards energy efficiency; (iv) The mandatory target for all residential buildings to achieve class F by 2030 (E by 2033), setting a clear roadmap for upgrading existing structures; (v) The creation of a new label system, with class A designated for ZEB buildings, and class G representing the 15 percent least efficient buildings at the national level. Meanwhile, classes B-F will be defined based on a well-balanced distribution of reference bands at national level.

The proposal has already undergone amendments from the European Parliament, resulting in a more stringent approach, particularly with regards to the minimum class requirement, which has been raised to E by 2030 (D by 2033). However, a major challenge lies in achieving stronger convergence among EPC systems, as currently, even at the national level, there is no unified standard. Addressing this issue will be crucial for the successful implementation of the legislation.

Figure 1: Energy performance certificate (APE)



Note: This chart displays an example of the Italian energy performance certificate (APE).

Inter-Ministerial Decree of 26 June 2015 – called *"requisiti minimi"* – which sets the minimum requirements for EPC classification at the national level. In the next section, we will discuss the new framework's main details and show that regional differences persist.

2.1 The APE framework

The Italian EPC provides crucial information regarding the energy efficiency of buildings, consisting of two main components: *(i)* the overall non-renewable energy performance index ($EP_{gl,nren}$), and *(ii)* the energy class that uses the $EP_{gl,nren}$ as input (Figure 1).

The $EP_{gl,nren}$ index estimates the overall energy consumption of a house and is measured in kilowatts per square meter (kWh/m2). This index does not measure actual energy consumption but is based on engineering models and assumptions. The actual implementation of the index mainly measures the non-renewable[13] primary energy requirements for winter heating and domestic hot water production because the measurement of the summer cooling and ventilation energy requirements is less precise. Considering this important caveat, we can consider the $EP_{gl,nren}$ index a standardized measure of the house's energy needs.

Energy classes are an intuitive labeling system that categorizes buildings based on energy efficiency. It employs a 10-letter scale (ranging from G to B and A1 to A4). For highly efficient buildings classified as A4, the property may receive an additional classification as Nearly Zero-

[13]When a house boasts renewable energy production systems, they are considered in calculating its $EP_{gl,ren}$, leading to a reduction in its $EP_{gl,nren}$ metric and consequently improving its overall energy label.

Energy Buildings (nZEB).[14]

The procedure for assigning the EPC label is not straightforward, and can be summarised in three steps:

- First, an expert should compute the overall energy performance of the house, $EP_{gl,nren}$, according to the technical standards specified by the regulation. Simplifying, the expert inputs the location and the values of some building characteristics in specific software, and the software calculates the index.

- Second, the expert computes the overall energy performance for a "reference building", $EP_{nren,rif,standard}$. This reference building is a structure that closely mirrors the existing building in terms of its physical attributes, such as geometry, orientation, location, purpose, and surrounding environment. However, it deviates from the real building because it is specifically designed to have predetermined thermal characteristics and energy parameters.

- Third, the expert calculates the ratio between $EP_{gl,nren}$ and $EP_{nren,rif,standard}$, and this ratio is transformed into the corresponding EPC label using the conversion coefficients reported in Figure A1. According to this classification approach, the reference building is a benchmark for separating the B and A1 energy efficiency classes.

Due to this regulatory framework, two houses may have different efficiency standards, although labeled under the same category. In particular, the label assigned to a specific building varies depending on its location for two reasons.

First, the estimate of energy performance and the parameters of the reference building depend on the property location's climate zone. In Italy, municipalities are categorized into six climate zones (from A, the warmest, to F, the coldest) based on the heating degree days (see Figure A2). Degree days are an indicator of the temperatures experienced in a specific area.[15] For example, the thermal characteristics for computing the energy performance of the reference building vary according to the climate zone level in which the real building is located.

[14]nZEB (*Edificio a energia quasi zero* in Italian) refers to a building with very high energy performance, where the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including the ones produced on-site or nearby. Starting in 2021, all newly constructed buildings or those undergoing extensive renovation must adhere to the European nZEB standard.

[15]The conversion from heating degree days to climate zones is accomplished using appropriate thresholds. While heating degree days provide continuous information on climatic conditions (see Figure A3), climate zones offer a simplified and discrete representation of the same data.

Second, the heterogeneity in energy labels stems from regional legislation. While the *"requisiti minimi"* Decree sets the minimum energy efficiency requirement for the reference building, regional legislation can implement more stringent standards. For example, Lombardy has been enforcing more rigorous parameters since 2015, while Emilia-Romagna took the initiative to adopt these parameters in 2019. The remaining regions of Italy, instead, have only implemented these more stringent standards starting from 2021. Moreover, the framework adopted by the autonomous provinces of Trento and Bolzano is unique, as it features a different labeling system.[16]

To sum up, the most effective approach to compare the efficiency of different buildings is by utilizing $EP_{gl,nren}$. Simply relying on the EPC label may not be suitable without considering other characteristics. Moreover, given the significant influence of regional legislation on the classification process, it is essential to carefully evaluate the applicability of results from one region to another. In the following, we will refer to the $EP_{gl,nren}$ index as the energy performance index and energy classes as energy labels.

3 Data and stylized facts

Information on the energy efficiency of the housing stock is very scarce in Italy, especially for estimating the impact of energy efficiency on property values. Although deeds for home purchases report the energy label since 2012, we cannot exploit this information because it is not digitalized. More recently, each region has activated regional digital registries to keep track of all energy efficiency certificates (including those made when renovating a property). The problem is that these registries are not uniform across regions and are not always publicly accessible. In addition, there is no information on property values in these registries. The latter problem also affects SIAPE, a centralized database managed by ENEA that contains information on all energy certifications in regional registers, including the $EP_{gl,nren}$.

In this paper, we leverage a large dataset of real estate listings on the Immobiliare.it platform, Italy's largest online portal for real estate services. As anticipated in Section 2, real estate advertisements include information on the energy efficiency of buildings since 2012. Our dataset

[16] Trento classifies buildings into ten distinct classes, ranging from G to D and C, C+, B, B+, A, and A+. On the other hand, Bolzano employs a classification system with eight classes, spanning from G to A, with the highest class being the Gold category. In both provinces, the classification is based on specific thresholds applied directly on $EP_{gl,nren}$, with the reference building as the upper limit.

contains partial information about energy efficiency. Indeed, we observe the energy label for almost all listings, while the energy performance index is missing or inaccurate. The dataset also reports several variables about the physical characteristics of homes, including the maintenance status, the location, and the asking price. We also track the history of each listing to capture any changes over time. Unfortunately, we do not observe the final transaction prices. However, Loberto et al. (2022) shows a correlation of 0.83 between the average listing prices and the average transaction prices – provided by the Italian Tax Office – at the neighborhood level. Data on Immobiliare.it is representative of the Italian housing market, and according to the Italian Housing Survey, above 80% of real estate agents advertise their listing on Immobiliare.it.

We construct the final dataset we follow the procedure to clean the original data illustrated by Loberto et al. (2022). Furthermore, we compute the distributions of price per square meter by city and maintenance status, and we winsorize the dataset by dropping the listings with price per square meter lower than the 1^{st} percentile and higher than the 99^{th} percentile of the reference distribution. Our final dataset includes 2.5 million listings between January 2018 and December 2022. In the next section, we will explore the main facts about energy efficiency.

3.1 Stylized facts

We start our analysis by comparing the distribution of listings across energy labels to the data available on SIAPE. Since microdata from the SIAPE are not accessible, our comparison will focus only on aggregate statistics on the EPC issued for the sale of properties between 2018 and 2022. For this comparison, we exclude from the Immobiliare.it dataset the listings located in Campania and Sardinia, as these regions have not yet transmitted their data to the SIAPE. Moreover, we exclude about 4.5% of listings that do not report the energy label because they are exempted.[17]

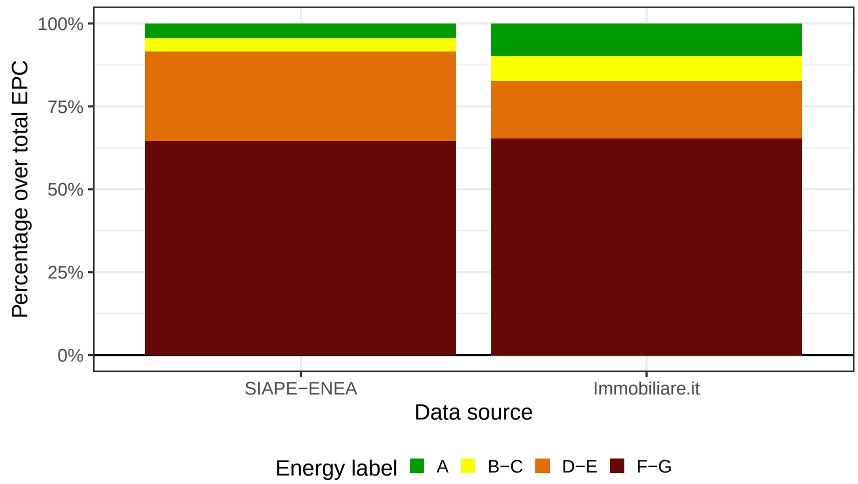
The composition of the Immobiliare.it sample seems consistent with the certificates in the SIAPE platform (Figure 2).[18] In 2022, about 65% of the listings had the lowest labels (F-G), and that closely mirrors the same share in the SIAPE dataset. However, Immobiliare.it tends to over-represent houses in higher energy classes. According to the Immobiliare.it data, about 17% of the listings had energy labels equal to C or better.[19] In the SIAPE dataset, this share is equal

[17] The regulation grants this exemption to houses in specific categories, such as, for example, stand-alone buildings with a total area less than 50 sm, agricultural or rural buildings, and buildings under construction.

[18] We computed the distribution on expired listings, which more closely track the transactions recorded in SIAPE.

[19] This percentage is similar to the average share of new house transactions in 2018-2021. ISTAT computes this

Figure 2: Comparison between SIAPE and Immobiliare.it



Note: This chart compares the distribution of energy certifications issued for house sales in SIAPE and for listings on Immobiliare.it. Data refer to 2022, and we consider only expired listings as they better proxy home sales. Energy label A comprises A1 to A4. To maintain consistency with SIAPE, we exclude from the Immobiliare.it sample the listings from Sardinia and Campania, as they do not participate in SIAPE.

to 8.5%. Several factors can explain this difference. For example, as data in Immobiliare.it are self-reported, sellers may show a better EPC label to enhance the attractiveness of the listing.[20]

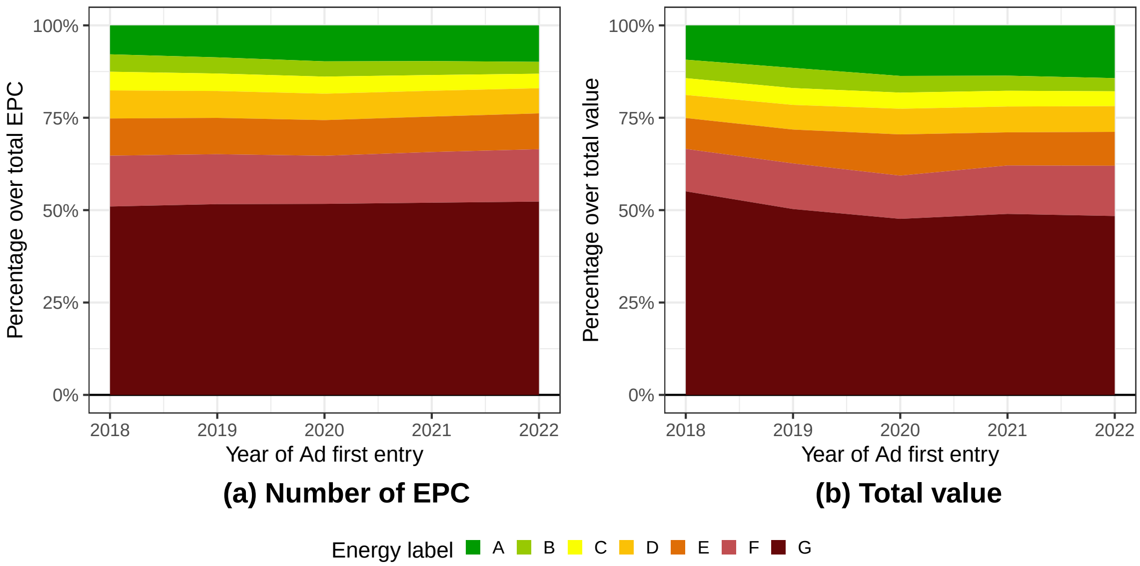
The distribution of listings across energy labels was stable between 2018 and 2022 (Figure 3a). When taking into account the corresponding real estate values, we find that the share of high energy-efficient houses in the total housing supply is higher and displays a larger increase over time (Figure 3b). In 2018 the value of homes with labels equal to or better than C was 19% of the total value of houses for sale, and this figure rose to 22% in 2022. Considering only the best energy labels (A1 to A4), Figure 4 shows that the share of high-efficiency homes is higher in the country's northeast region.[21] This distribution may be attributed to two factors besides the influence of regional regulations: *(i)* the different climatic conditions across territories, which significantly affects the convenience of energy efficiency; *(ii)* the increased awareness and responsiveness of the population to environmental and climate-related concerns.

statistic to compile the Italian residential property type index. ISTAT includes in this category also homes renovated and sold by construction companies, which are not necessarily energy-efficient (e.g., renovation of historic buildings).

[20]Moreover, the seller might utilize a recent certificate issued for other instances, such as a relevant retrofitting, which indicates higher energy labels according to SIAPE data. Consequently, we potentially underestimate the higher energy labels using SIAPE's data issued specifically for sales purposes.

[21]Figure 4 also displays the dynamic of the share of listings with energy label A1-A4 in the Italian provinces over time. We have observed an increase in the share of high-efficiency dwellings for most of these provinces, while the share has decreased in some provinces. This is probably due to the sample size of these provinces being relatively small, causing the percentages to fluctuate significantly when the sample size is reduced by just a few units.

Figure 3: Housing supply and energy-efficiency



Note: This chart reports the distribution of energy certifications for listings on Immobiliare.it. For each year, we consider only new listings. Energy label A comprises A1 to A4. Panel (a) reports the percentage relative frequency for each energy label, and panel (b) displays the share of each label on the total value of supply.

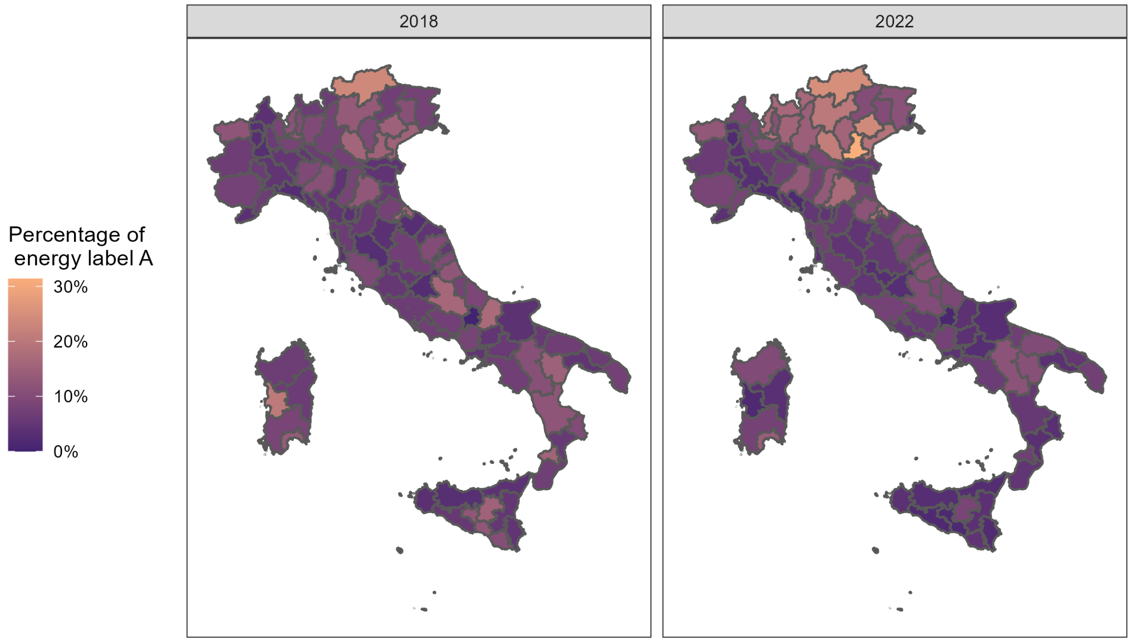
House prices are (unconditionally) higher for homes with better energy labels (Figure 5). In 2022, the average price of a house with a label in *A1-A4* was about 40% higher than a house with a label in *F-G*. Moreover, the difference between the A and other labels grows over time. Label G average property prices are lower than the other classes starting only from 2020, pointing to significant recomposition effects.[22]

Identifying how much the energy label affects the price of a house is difficult because energy efficiency can be correlated with other characteristics of the homes. For example, considering that the price per square meter decreases with the size of the properties, the observed price difference might be merely masking a systematic differential in houses' size. Nonetheless, even after controlling for this variable, the price of the most energy-efficient houses is higher.

Moreover, Figure 6 shows that homes with better maintenance status also tend to have better EPC ratings. Nevertheless, the heterogeneity in energy labels, even for the worst status, is important for our econometric analysis, as it allows us to disentangle between the premium associated with the energy label and the premium associated with the state of maintenance. Finally, Figure

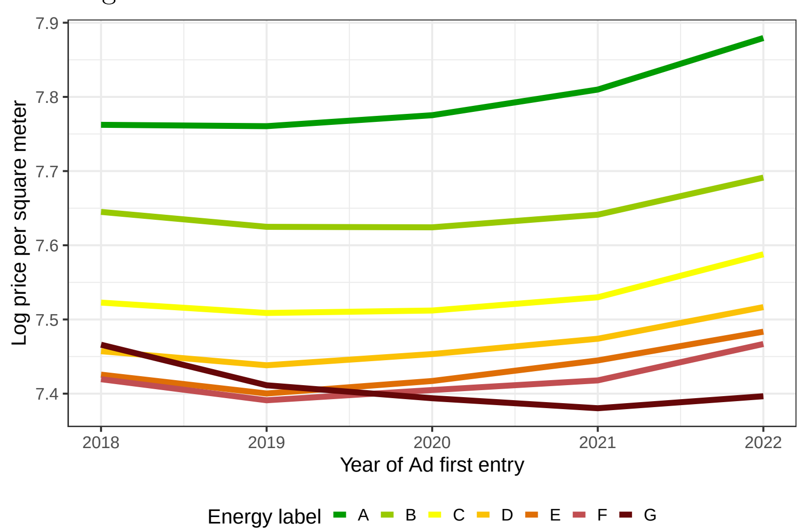
[22]This trend could be justified by the fact that the importance of EPC has increased over the years, preventing them from being sought solely for compliance with legal obligations. This may have led to a higher issuance of class G in the past certificates, even for properties of superior quality, as probably indicated by their price.

Figure 4: The supply of high energy-efficiency homes



Note: This chart displays the share of listings with energy label A in the Italian provinces in 2018 (left panel) and 2022 (right panel). The percentage is computed on the total value of supply. For each year, we consider only new listings.

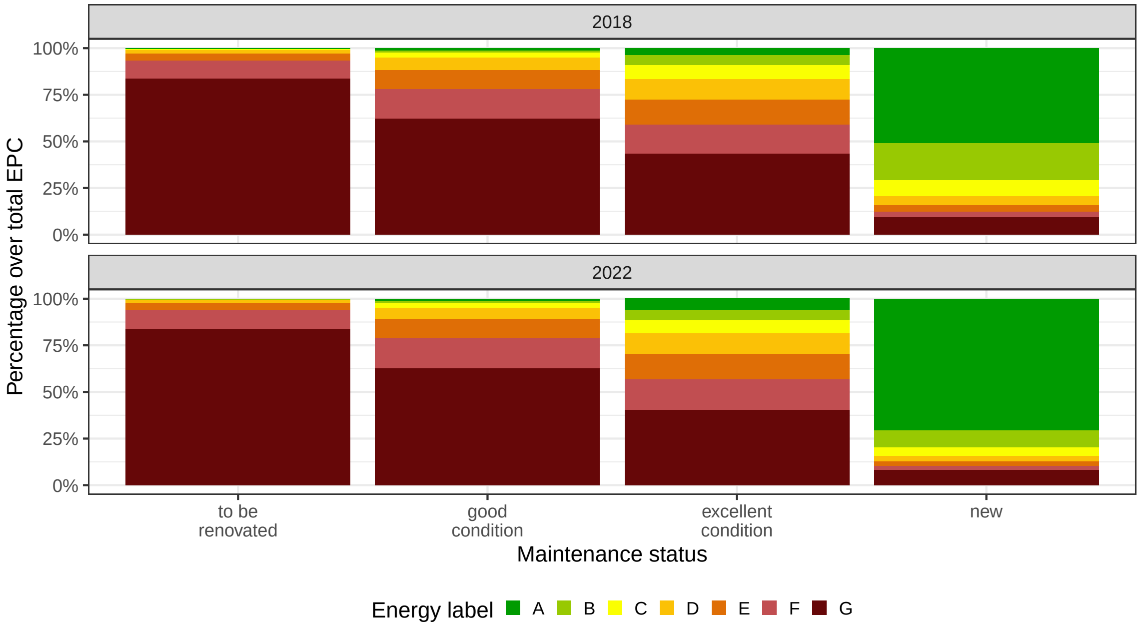
Figure 5: Energy efficiency and house prices



Note: This chart displays the evolution of the average listing prices per sm (logarithm) over time by energy label between 2018 and 2022. For each year, we consider only new listings.

6 displays that the average EPC quality has improved over time across all types of maintenance status.

Figure 6: Energy efficiency and maintenance status



Note: This chart displays the distribution of energy labels by maintenance status in the Immobiliare.it sample in 2018 (upper panel) and 2022 (lower panel). The percentage is computed on the total value of supply. For each year, we consider only new listings.

To sum up, the share of energy-efficient houses is growing over time, and their price is much higher than that of low-energy-efficient houses. Energy-efficient houses have a higher quality also with respect to other house characteristics, so their prices are much higher than average house prices and they are not affordable for many households. In the next section, instead, we will estimate the impact of the energy label on house prices for all other characteristics being equal.

4 The capitalization of energy efficiency in house prices

Measuring to which extent energy efficiency is capitalized in house prices is crucial for performing a cost-benefit analysis of investments in energy efficiency and for designing optimal incentive policies. In this section, we quantify the impact of energy labels on the price of houses. Specifically, we measure the price differential of a house with a generic energy label $m \in \{A, B, C, D, E, F\}$ versus a house with energy label G. As before, label A merges energy classes *A1*-*A4*.

We use monthly data between January 2018 and December 2022, and we exclude listings in Trentino Alto Adige and Valle d'Aosta, as we are concerned about significant differences in the regulation compared to the national legislation.[23] We also exclude listings that are exempted from having an energy label. Then, we estimate the following OLS regression:

$$y_{i,k,t} = \alpha_k + \xi_t + \sum_{m\in\{A,B,C,D,E,F\}} \beta_m \Theta_{i,m} + \gamma \mathbf{X}_i + \sum S_i \times D_{i,ys} + \zeta_{i,j,ys} + \varepsilon_{i,k,t} \quad (1)$$

where $y_{i,k,t}$ is the logarithm of listing price per square meter of house i in neighborhood k which is visible on Immobiliare.it during the month t.[24] We include neighborhood and monthly fixed effects, α_k and ξ_t, to control for time-invariant unobservables at the neighborhood level and common trends across neighborhoods.[25] Our coefficients of interest are β_A,...,β_F. Since $\Theta_{i,m}$ are dummy variables equal to one if the energy label is equal to m, with $m \in \{A, B, C, D, E, F\}$, the estimated coefficient gives the percentage price differential between the energy label m and G. We control for several characteristics of the house, $\mathbf{X}_i$, including the following: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, and garden type.

A key variable correlated with energy performance is the maintenance status. Since 2020, construction costs increased quickly, causing an increase in the price differential between renovated and to-be-renovated homes (Crispino and Loberto, 2023a). Since renovated homes usually have higher energy efficiency, introducing in equation (1) a time-invariant coefficient for the maintenance status may undermine the identification of the capitalization of the energy label in house prices.[26] Therefore, we interact the variable maintenance status, S_i, with year-semester variables, $D_{i,ys}$, to have a time-varying measure of the contribution of maintenance status to the price.

Finally, $\zeta_{i,j,ys}$ are year-semester fixed effects at the NUTS-1 level interacted with the degree of urbanization of the municipality.[27] This is motivated by the fact that the COVID-19 pandemic caused a significant change in housing demand in Italy (Guglielminetti et al., 2021). In particular,

[23] We exclude Valle d'Aosta because of the limited sample size.

[24] Neighborhoods are based on the zoning developed by the Italian Tax Office (OMI zoning). The Italian territory is partitioned in about 28,000 neighborhoods.

[25] We estimated a specification with interacted neighborhood-time fixed effects and results are similar to those of the baseline regression.

[26] That is a minor issue in estimating the baseline model but particularly relevant when estimating the evolution over time of the capitalization of the energy label.

[27] The degree of urbanization is a categorical variable. The Italian National Statistical Institute classifies each municipality as a city, a suburb, or a rural area.

housing demand increased much more strongly in rural areas and suburbs compared to cities. These interacted fixed-effects control for these heterogeneous trends in housing demand related to the congestion of the municipality where the house is located.[28]

Standard errors are clustered at the commuting zone level.[29] Our results, however, are robust to an alternative set of standard errors.

An implicit assumption of our specification is that there are no unobservables that may be correlated with the asking price and the energy label, i.e., conditional on all control variables, the energy label is uncorrelated with the error term. We do not think this can be a major problem for two reasons. First, we take advantage of within-neighborhood variability, so we will compare houses that benefit from the same external amenities. The definition of neighborhood is the one developed by the Italian Tax Office (*microzona OMI*). Neighborhoods are designed based on the characteristics of the housing stock and some socioeconomic variables to maximize the similarity of the housing stock – and house prices – in each neighborhood. We also exploit a more granular definition of location – census tracts – for robustness. Second, we have a specific variable that identifies the maintenance status of the dwellings. Thus, we compare houses with similar maintenance status within the same neighborhood. Unfortunately, we cannot extrapolate our estimates on the value of energy efficiency to the entire housing stock. Our sample includes only houses listed for sale. Because of the well-known data gaps about the characteristics of the Italian housing stock, we cannot evaluate to what extent our dataset is biased.

Column 1 in Table 1 and Figure 7a report the estimation results. As expected, the relation between house prices and energy efficiency is positively monotonic. Indeed, the percentage price differential of a house with energy label F compared to the energy label G is 3%. For a house with energy label A, instead, the premium is about 25%. This figure is significantly lower than the unconditional price differential we observed in Section 3.1 because energy efficiency is correlated with other dimensions of homes' quality.[30]

[28] We also estimated a more demanding specification with year-semester fixed effects at the regional level interacted with the degree of urbanization of the municipality. This specification would also control for changes in regulatory standards at the regional level. However, the results are very close to those of baseline regression.

[29] Commuting zones (*Sistemi locali del lavoro*) are identified by ISTAT based on the mobility patters of the population. Currently, Italy is partitioned in about 700 commuting zones.

[30] To assess the robustness of the main results, we estimated equation (1) replacing the neighborhood fixed effects with census tract fixed effects. In Italy, census tracts are very small areas including a limited number of buildings. For example, considering only census tracts containing at least 10 dwellings (about 75% of the total), the median area is equivalent to that of a square with a side of just under 200 meters. In these small areas the heterogeneity

Table 1: Capitalization of energy labels

	Price €/sm (logarithm)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Full country	Climate zone				
		Zone A-B	Zone C	Zone D	Zone E	Zone F
Energy label: A	0.227***	0.113***	0.147***	0.145***	0.282***	0.313***
	(0.015)	(0.014)	(0.017)	(0.015)	(0.017)	(0.030)
Energy label: B	0.190***	0.129***	0.126***	0.129***	0.224***	0.278***
	(0.009)	(0.023)	(0.014)	(0.016)	(0.013)	(0.023)
Energy label: C	0.145***	0.096***	0.099***	0.107***	0.172***	0.217***
	(0.007)	(0.013)	(0.010)	(0.009)	(0.010)	(0.018)
Energy label: D	0.106***	0.084***	0.057***	0.078***	0.129***	0.150***
	(0.007)	(0.011)	(0.007)	(0.010)	(0.011)	(0.011)
Energy label: E	0.070***	0.045***	0.043***	0.044***	0.091***	0.115***
	(0.007)	(0.010)	(0.006)	(0.006)	(0.009)	(0.012)
Energy label: F	0.033***	0.015**	0.022***	0.021***	0.048***	0.082***
	(0.005)	(0.007)	(0.005)	(0.005)	(0.006)	(0.011)
Observations	15,905,156	636,065	2,136,654	4,339,142	8,359,457	433,838
R^2	0.784	0.619	0.772	0.807	0.762	0.781
Within R^2	0.145	0.129	0.116	0.117	0.181	0.142
Control variables	✓	✓	✓	✓	✓	✓
Neighborhood	✓	✓	✓	✓	✓	✓
Year-Month	✓	✓	✓	✓	✓	✓
Year-Semester-Maintenance status	✓	✓	✓	✓	✓	✓
Year-Semester-Density-NUTS1	✓	✓	✓	✓	✓	✓

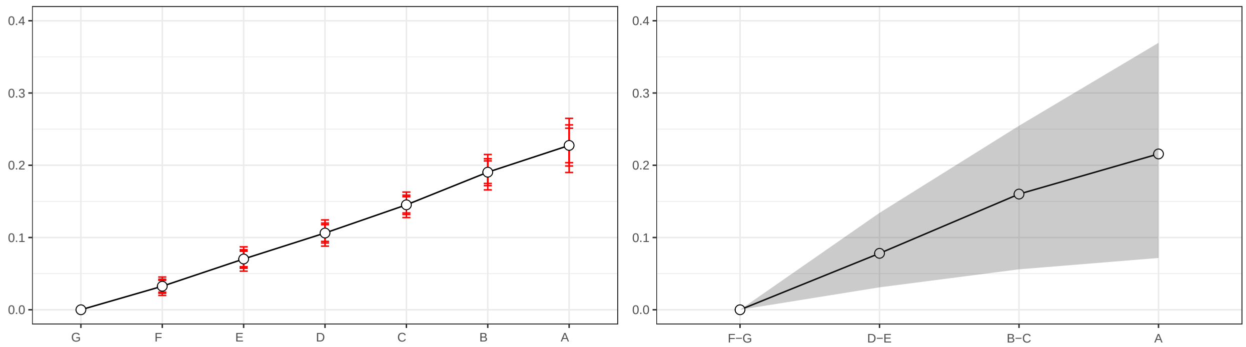
Note: This table displays the results of the OLS estimation of equation (1). The dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. The regression includes neighborhood fixed effects. Monthly data for the period January 2018-December 2022. Column 1 reports the results when equation (1) is estimated on the full sample. Columns 2-6 show the results when the equation is estimated separately by climate zone, from the hottest (A-B) to the coldest (F). Standard errors are clustered at the commuting zone level.

An important result is that the impact of energy efficiency on house prices is very heterogeneous across the country. To investigate the dispersion in the extent of capitalization, we estimate a simplified version of equation (1) for each province. In particular, as the sample size can be an issue in several provinces, we run the regression on annual data, and we pool the energy labels into the categories F-G, D-E, B-C, and A.[31] Figure 7b displays that the median estimates for the

of the housing stock is much lower than in a neighborhood, and this relaxes concerns that the effect we find may be related to some unobserved amenity correlated with the energy label. Table A1 in Appendix A shows that the estimates over the full sample and those by climate zone are very similar to our baseline results.

[31] Furthermore, we do not control for time-varying heterogeneous shocks correlated with population density because

Figure 7: Capitalization of energy labels



(a) Full country

(b) By province

Note: This chart reports the capitalization of the energy labels into house prices. Panel a) shows the results of the OLS estimation of equation (1) in the full sample. The dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. Monthly data for the period January 2018-December 2022. Standard errors are clustered at the commuting zone level. Panel b) displays the median estimates across provinces. The grey area covers the distribution of the estimates between the 5^{th} and the 95^{th} percentiles.

coefficients associated with the energy labels are close to the average estimates. The dispersion, however, is huge. For example, considering the 5^{th} and the 95^{th} percentile of the distribution of the estimates (the range of the grey area in fig. 7b), we find that the price premium for homes with energy label A varies between 7 and 45%. Figure A4 shows how the average premium for label A homes changes across the country, and this premium is usually larger in northern Italy.[32]

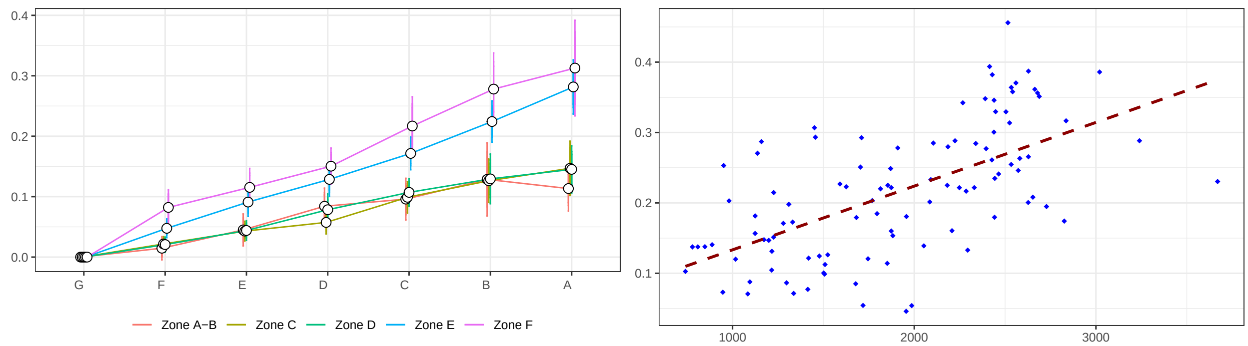
Therefore, a first step in investigating the reasons for this large dispersion is considering the heterogeneity in climate conditions across the country. In that regard, we run separate regressions by climate zone. In particular, we estimate equation (1) for each climate zone, from the warmer (zone A-B) to the colder (zone F). Columns 2-6 in Table 1 and Figure 8a show that climate conditions are indeed a main driver of the dispersion in the estimates of the impact of energy efficiency. For houses in zones A-B to D, the price premium on homes with energy label A is between 12% and 16%, while in zones E and F, the premium is 33 and 37%, respectively.

Figure 8b displays on the y-axis the estimated house price differential between the energy label A and F-G and on the x-axis the average measure of climate conditions in each province. There

there is limited or no variation in this dimension in most provinces.

[32] The map shows that provinces hosting major metropolitan areas like Rome, Milan, and Naples tend to exhibit a reduced premium with respect to the other provinces in the same region. In these provinces, average housing prices are much higher than other provinces. Consequently, the energy-efficiency premium as a percentage of the average prices may be lower than nearby provinces.

Figure 8: Capitalization of energy labels and climate



(a) Full country (b) By province

Note: This chart reports the capitalization of the energy labels into house prices in different climate zones. Panel a) shows the results of the OLS estimation of equation (1) by climate zone. The dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. Monthly data for the period January 2018-December 2022. Standard errors are clustered at the commuting zone level. Panel b) displays the quality-adjusted percentage price differential between label A and label F-G (y-axis) and the average number of degree days (x-axis) by province.

is a clear positive correlation between temperatures and the capitalization of the A-label in house prices.[33] However, we also notice that provinces with similar climate conditions may have different capitalization levels. That could be due to several factors. For example, there could be differences in household preferences for energy efficiency or in zoning regulations. Unfortunately, identifying the causes of these differences would require knowing not only the energy labels but also the energy performance index of the home.

Finally, we investigate if the extent of capitalization of energy label has changed over time by estimating (1) separately by year (Figure A5 in Appendix A). On average, estimates are quite stable over time. However, in some climate zone in 2021 and 2022 there is a higher capitalization for energy classes A and B. Unfortunately, we cannot say what are the determinants of these trends. Indeed, there are two potential factors explaining these patterns. First, increases in energy costs or growing concerns about climate change may have caused a greater demand for more energy-efficient homes. Second, the increase in the extent of capitalization could be due to the more restrictive regulatory criteria. Information about the energy performance index could allow the identification of the contribution of both channels.

[33]The energy efficiency premium might be partly attributed to the application of discounts on mortgage interest rates for more energy-efficient buildings. As indicated by a recent consumer survey, the average discount in Italy is approximately 13 bp. Unfortunately, our analysis cannot consider this variable as a control due to the lack of granular data. Moreover, there is no evidence indicating territorial heterogeneity in the granted discounts.

Summing up, energy labels are capitalized into house prices and the extent of capitalization is heterogeneous across country. Our data, unfortunately, do not allow to identify the causes of this dispersion.

5 Discussion and conclusions

This paper is the first step in estimating the extent of the capitalization of energy efficiency into house prices in Italy. Based on a large dataset of home sale listings from the largest online portal for house sales in Italy, we find that the listing price of a house increases with the energy label. The price of the most energy-efficient homes is ceteris paribus 25% higher than the worst energy-performing houses. We also find a large dispersion in the extent of the capitalization of energy labels across provinces, partly explained by the significant heterogeneity in climate conditions and in technical standards for measuring energy efficiency.

Our analysis has some limitations due to the lack of some key data. The main problem is that we can only exploit the energy labels, which are not comparable between different localities. Information about dwellings' energy performance index, which is a direct measure of energy efficiency and is more comparable than energy labels across different municipalities, is not publicly available. Consequently, as repeatedly pointed out in the paper, we only estimate the price differential attributable to the energy labels.

Knowing the energy performance index would allow us to better interpret the capitalization differentials we observe between provinces. For example, the differentials we observe between warmer and colder climate zones may be due to different levels of energy performance. Indeed, energy performance is a more pressing need in colder areas and it may then be the case that in warm areas the theoretical energy consumption is low even though the degree of thermal insulation of the houses is lower. Moreover, according to the aggregate SIAPE data, the difference in the $EP_{gl,nren}$ between the worst label (G) and the best label (A1) is much higher in the coldest regions compared to the warmest. Consequently, if we assume equivalent retrofitting costs for a particular type of investment, achieving energy label A in warmer localities plausibly requires a lower investment, which can explain the lower premium for label A homes.

However, other possible explanations exist for the dispersion of the degree of energy label capitalization. For example, there could be differences in household preferences for energy efficiency. That would not be surprising because the degree of attention to the issue of climate change in Italy varies widely among provinces (Crispino and Loberto, 2023b). In particular, the degree of attention to climate change is highest in Central and Northern Italy, where we also observe the highest capitalization values of energy labels. Of course, this could only be a correlation, and knowing the values of the energy performance of houses would help in investigating the potential causal link.

Moreover, even knowing the energy performance values may not be sufficient because energy performance indices result from a complex algorithm and even minor methodological discrepancies across regions could lead to significant differences in the final output. Unfortunately, regulations are complicated and technically complex, so it is difficult to assess the relevance of this issue.

Despite these caveats, our contribution is relevant for two reasons. First, we are the first to provide granular estimates of the impact of energy labels on house prices in Italy. Second, energy labels, despite their limitations, are taken as a salient signal by market participants and are often taken as the benchmark for some policies. For example, the most recent energy efficiency subsidy program carried out in Italy, the SuperEcobonus 110%, granted government subsidies only if the retrofitting work improved the energy label of the property by two levels. Although conducting a cost-benefit evaluation of this program is beyond the scope of this paper, our estimates show that the private benefits from these investments – as measured by the homes' appreciation – were very different across localities. However, ENEA's report on Superbonus utilization revealed that the average retrofitting incentives were very similar across regions, approaching the maximum allowable limit. This apparent uniformity can likely be attributed to the exceptionally generous nature of this specific scheme, which incentivizes 110% of the total retrofitting costs up to a specific threshold. Therefore, a policy that accounted also for the individual benefits of retrofitting while factoring in the regional disparities in house price appreciation (reflecting private return on investment) may have resulted in a better allocation also for the public funds.

Looking forward, the priority is collecting data on the energy performance index ($EP_{gl,nren}$, in the notation of Section 2). That would allow us to better understand how the housing market incorporates energy efficiency into prices and the role of household preferences. This information would also be very informative for designing incentive programs for housing retrofitting or in the debate about the implications of new European regulations penalizing energy-inefficient homes.

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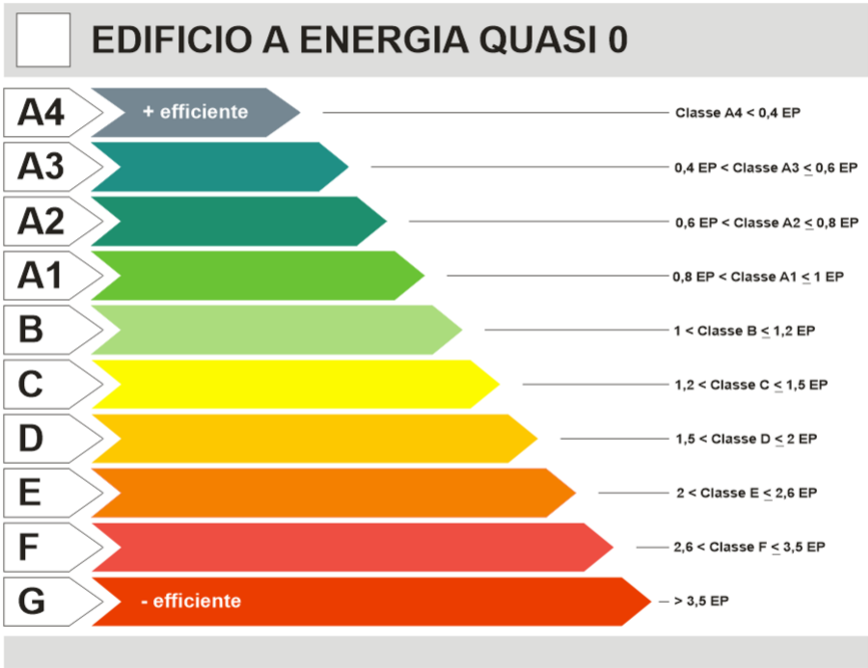
Appendix

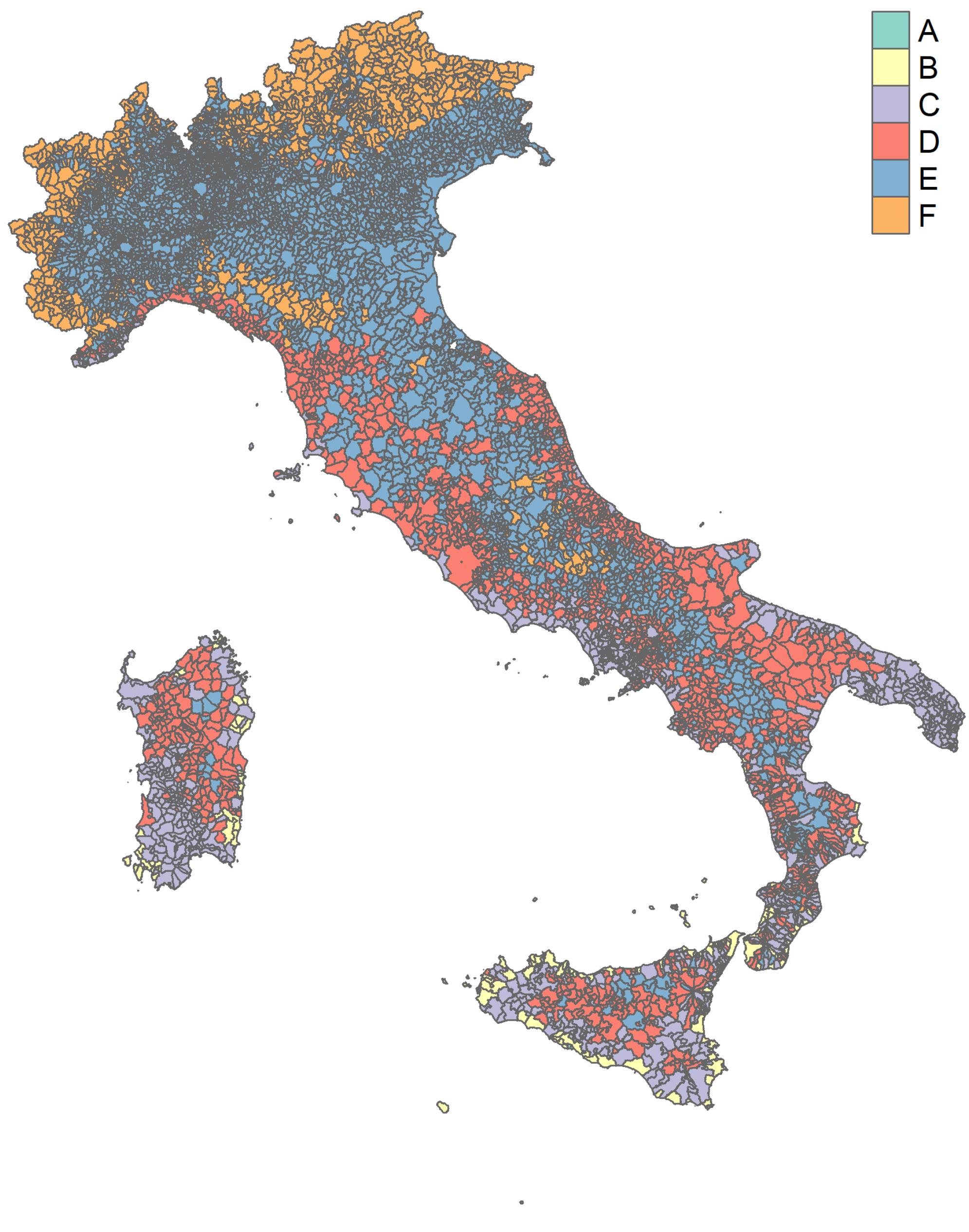
A Figures and tables

Figure A1: Assignment of the energy label



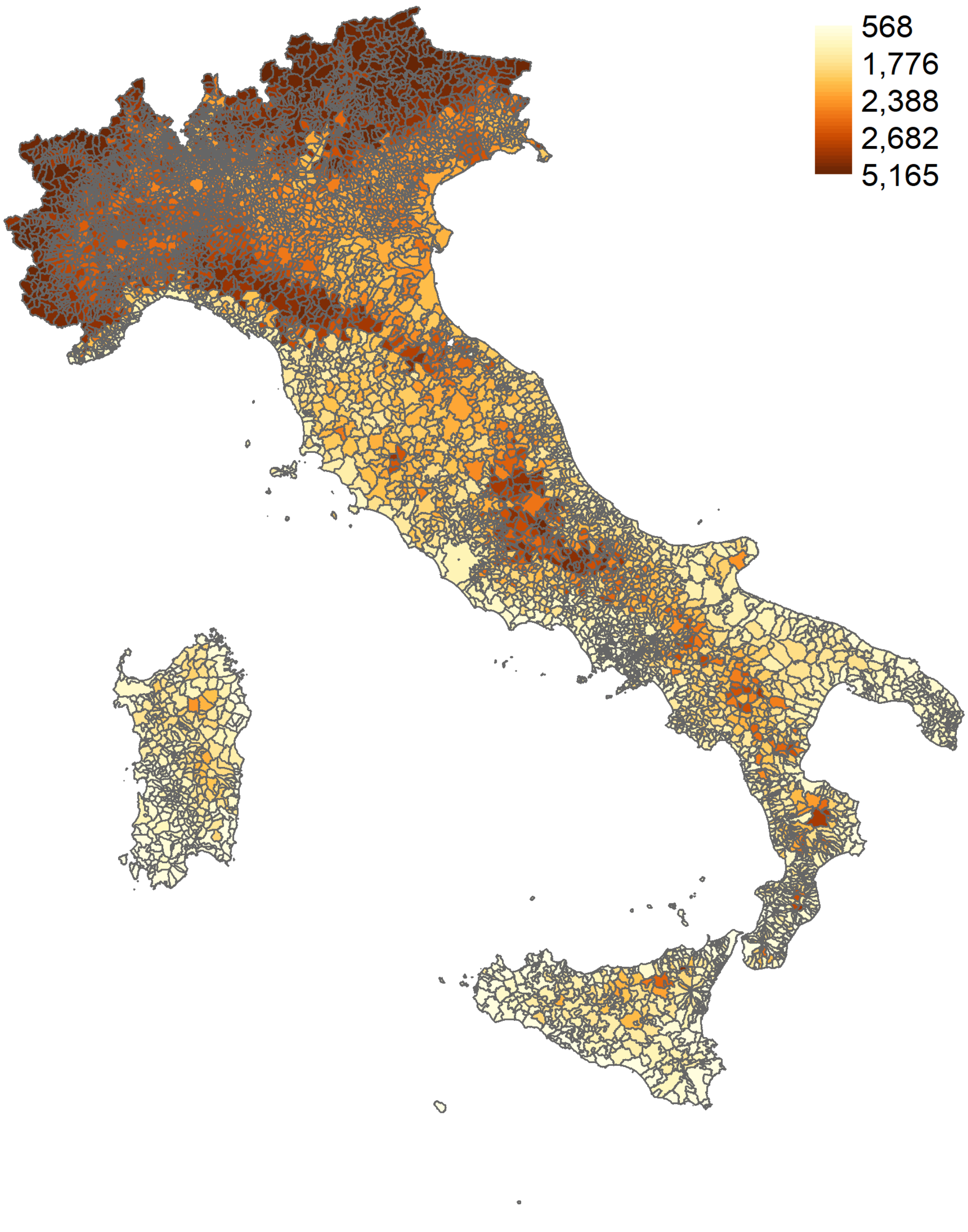
Note: This chart reports the conversion table for assigning the energy label as determined by *"requisiti minimi"* Decree. EP is computed as the ratio between $EP_{gl,nren}$ and $EP_{nren,rif,standard}$.

Figure A2: Climate zones



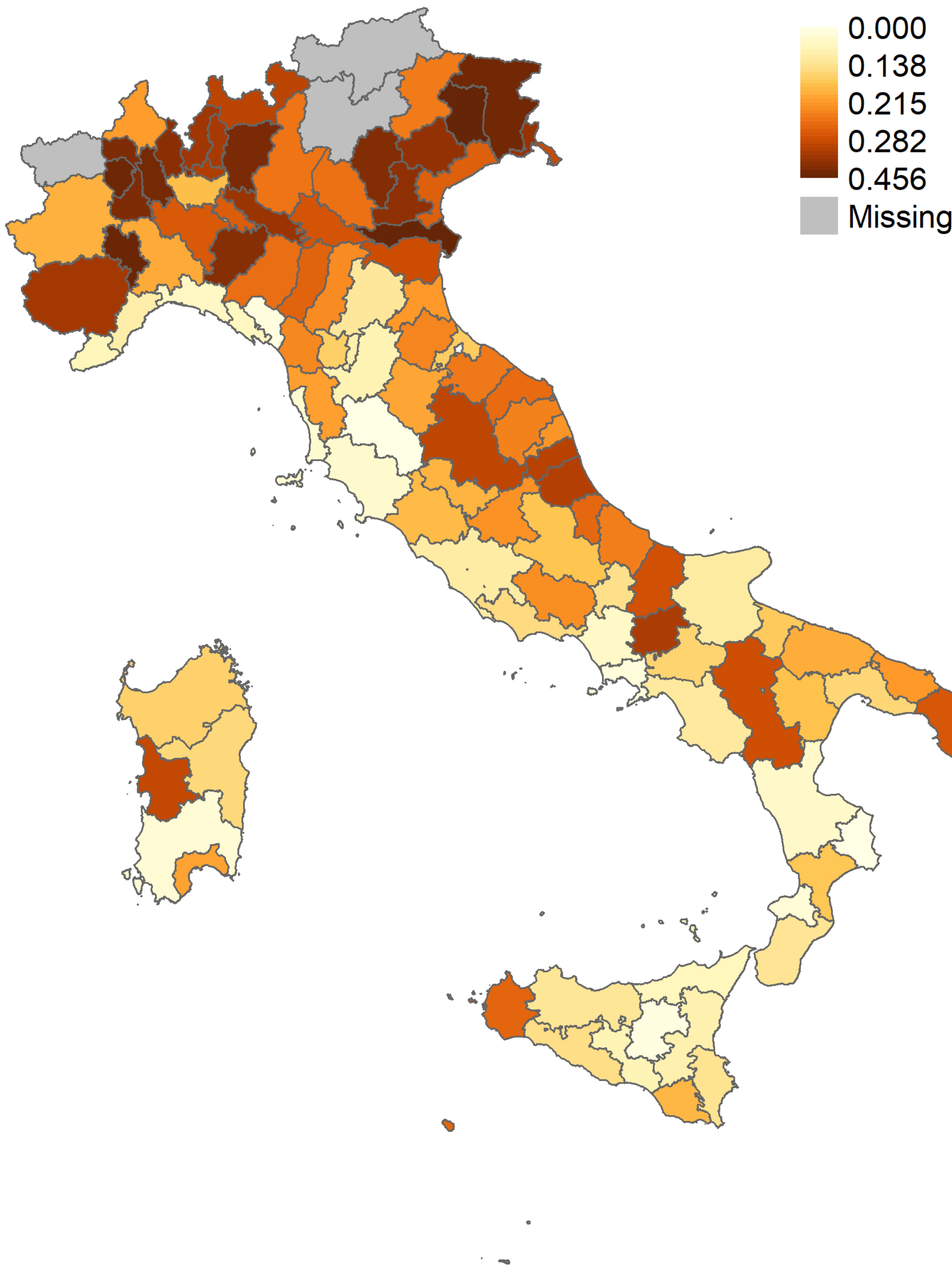
Note: This chart reports the climate zone of the Italian municipalities on January 1, 2020.

Figure A3: HEATING DEGREE DAYS



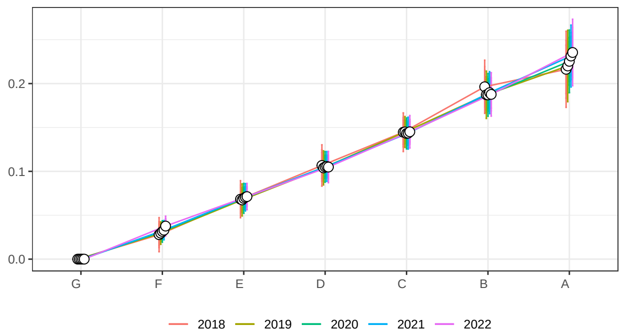
Note: This chart reports the heating degree days of the Italian municipalities on January 1, 2020.

Figure A4: Capitalization of label *A*

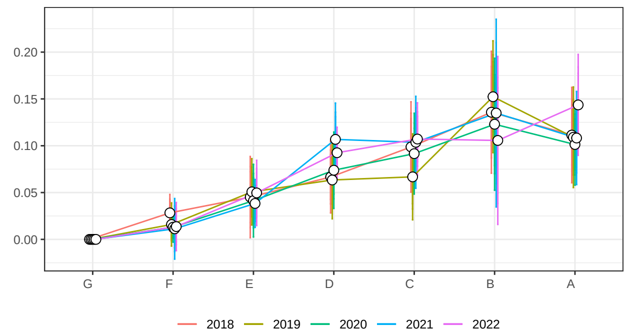


Note: This chart reports the capitalization of the energy label A into house prices in different provinces. The values are the coefficient associated with the energy label A in an OLS regression where the dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. Monthly data for the period January 2019-December 2022.

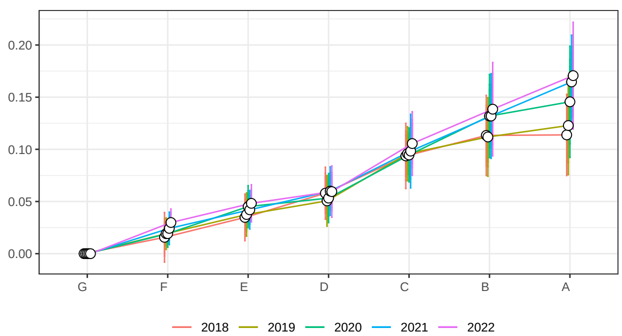
Figure A5: Capitalization of energy labels over time



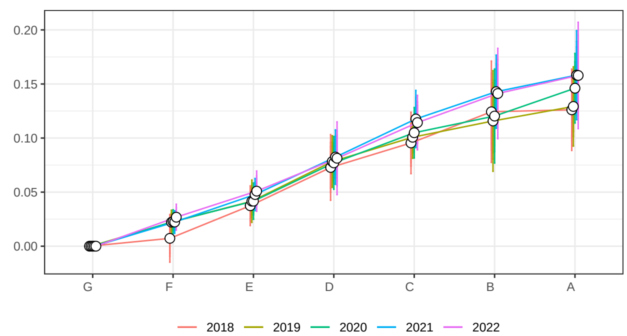
(a) Full country



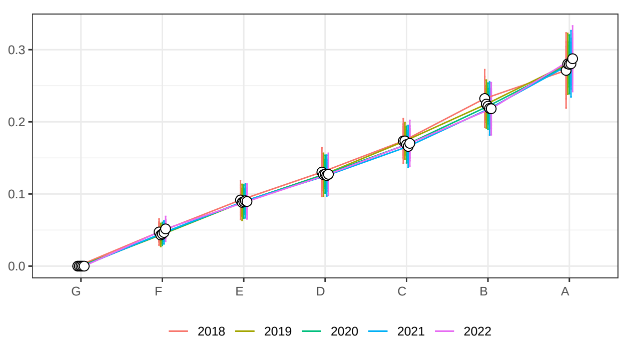
(b) Climate zone 1



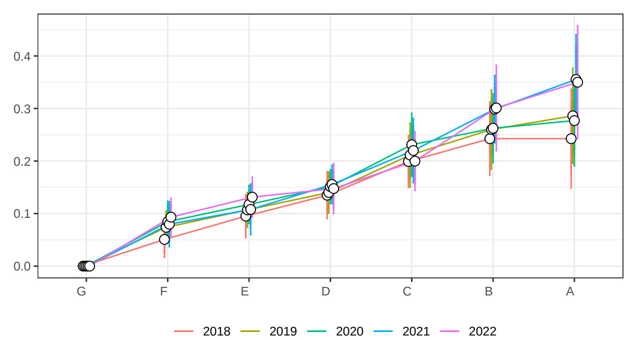
(c) Climate zone 2



(d) Climate zone 3



(e) Climate zone 4



(f) Climate zone 5

Note: This chart reports the capitalization of the energy labels into house prices by year. Panel a) shows the results of the OLS estimation of equation (1) in the full sample. The dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. Monthly data for the period January 2018-December 2022. Standard errors are clustered at the commuting zone level. Panel b)-f) display estimates by climate zones.

Table A1: Capitalization of energy labels. Robustness

	Price €/sm (logarithm)					
	(1)	(2)	(3)	(4)	(5)	(6)
	Full country	Climate zone				
		Zone A-B	Zone C	Zone D	Zone E	Zone F
Energy label: A	0.222***	0.109***	0.134***	0.138***	0.279***	0.282***
	(0.015)	(0.014)	(0.017)	(0.015)	(0.016)	(0.028)
Energy label: B	0.182***	0.121***	0.113***	0.117***	0.218***	0.266***
	(0.010)	(0.021)	(0.012)	(0.015)	(0.012)	(0.022)
Energy label: C	0.135***	0.095***	0.091***	0.093***	0.162***	0.190***
	(0.007)	(0.012)	(0.009)	(0.010)	(0.011)	(0.016)
Energy label: D	0.098***	0.075***	0.046***	0.070***	0.120***	0.140***
	(0.007)	(0.011)	(0.006)	(0.010)	(0.011)	(0.012)
Energy label: E	0.066***	0.041***	0.038***	0.040***	0.087***	0.103***
	(0.006)	(0.009)	(0.005)	(0.007)	(0.009)	(0.012)
Energy label: F	0.031***	0.017**	0.020***	0.019***	0.046***	0.071***
	(0.005)	(0.008)	(0.004)	(0.005)	(0.006)	(0.011)
Observations	15,905,156	636,065	2,136,654	4,339,142	8,359,457	433,838
R^2	0.840	0.744	0.838	0.856	0.821	0.835
Within R^2	0.145	0.120	0.121	0.119	0.180	0.133
Census tract	✓	✓	✓	✓	✓	✓
Year-Month	✓	✓	✓	✓	✓	✓
Year-Semester-Maintenance status	✓	✓	✓	✓	✓	✓
Year-Semester-Density-NUTS1	✓	✓	✓	✓	✓	✓

Note: This table displays the results of the OLS estimation of equation (1). The dependent variable is the logarithm of the price per sm. Covariates include the following variables: property type (apartment or single-family home), floor area, floor level, elevator, number of bathrooms, terrace, garage, garden type, and maintenance status. The regression includes census tracts fixed effects. Monthly data for the period January 2018-December 2022. Standard errors are clustered at the commuting zone level.

B Legal framework

A European Regulation (milestone)

- EPBD: Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings
- "EPBD recast": Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)
- "EPBD recast 2021": Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the energy performance of buildings (recast)

B National Regulation (milestone)

- D. Lgs. 192/2005: Attuazione della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia
- Requisiti minimi: Decreto interministeriale 26 giugno 2015 - Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici

C Regional Regulation (cited)

- Lombardy: Decreto n. 6480 del 30 luglio 2015 "Disposizioni in merito alla disciplina per l'efficienza energetica degli edifici e per il relativo attestato di prestazione energetica a seguito della D.G.R. 3868 del 17.7.2015"
- Emilia Romagna: D.G.R. n. 967, 20 luglio 2015 "Approvazione dell'atto di coordinamento tecnico regionale per la definizione dei requisiti minimi di prestazione energetica degli edifici (artt. 25 e 25-bis L.R. 26/2004 e s.m.)"
- Trento: Deliberazione di Giunta provinciale n. 162/2016 Modificazioni ed integrazioni al d.P.P. 13 luglio 2009, n. 11-13/Leg recante "Disposizioni regolamentari in materia di edilizia sostenibile in attuazione del titolo IV della legge provinciale 4 marzo 2008, n. 1 (Pianificazione urbanistica e governo del territorio)"

- Bolzano: Direttiva tecnica CasaClima agosto 2011