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Are composite valuation frameworks better than €/m² for Belgian housing?

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Note

For this document, Perplexity and Claude have been used to propose formulations and structure, but the text is original, except the extracts explicitly mentioned as coming from other sources, which are mentioned in footnotes.

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Introduction: Is €/m^2 a sufficient tool to assess dwelling's value?

For most Belgian households, buying a dwelling is one of the most important financial decisions of their lives. It often results from years of saving and building borrowing capacity. The purchased property often accounts for a large share of their total wealth. Housing choices are also closely linked to life events: the arrival of a newborn may require an extra room, or children leaving home may make it unnecessary to maintain a large house with multiple bedrooms. In each case, households must decide not only whether to buy, but what they are really buying when they choose one dwelling over another.

On the ground, buyers and professionals mainly rely on the price per square meter (€/m²) as the dominant reference for comparing properties and locations. This metric is easy to communicate and has become a reference in real-estate practices and media publications. Yet buyers often have difficulty getting a clear understanding of what lies behind a €/m² figure.

This thesis investigates the possibility of obtaining more accurate and intelligible criteria to assess Belgian housing value than €/m² alone. It is based on the hedonic pricing and spatial equilibrium literatures, which model dwellings as bundles of characteristics and interpret observed prices as the outcome of implicit valuations of these characteristics. Building on this framework and on recent Belgian empirical work, the focus lies on five families of metrics that appear to systematically influence prices: energy performance, accessibility and commuting time, walkability and amenity access, environmental quality, and social and fiscal factors.

The first part of the thesis is research-oriented. It reviews the international and Belgian literature on these metrics. It also documents specific features of the Belgian housing market and describes an empirical strategy that combines hedonic regressions, quantile methods, interpretable machine-learning techniques and geographic information systems (GIS). This empirical framework is then applied to commune-level data for the period 2011-2023. Based on this framework, an estimation is made on how the identified metrics shape residential property values across the three Belgian regions and across the price distribution.

The second part is more reflective. It explains what shaped the research question over time and how empirical choices were made. It also discusses the strengths and weaknesses of each empirical approach and confronts the findings with the initial intuitions. Together, these two parts aim to provide a structured answer to the research question and a transparent view of how this answer was built.

Then the last sections clarify the main limitations of the work to provide a clear scope and present multiple further research that could bring even more substance to the existing literature.

Part 1 Rethinking housing value: Theory, evidence, and a Belgian test

1. The €/m² illusion: Framing the problem and the question

Real estate is a central asset in Belgian household wealth and a key indicator for macroeconomic and regulatory shocks. Yet, both professionals and media rely on €/m² as the dominant reference for comparing dwellings and communes. This assumes implicitly that all non-area attributes are identical or negligible. The hedonic literature (presented in section 8.1), written by Lancaster and Rosen, has, over time, emphasized that this assumption is almost always wrong. Buyers derive utility from a bundle of characteristics that includes not only the floor area, but also energy performance, accessibility, environmental quality, walkability and local public services.

Belgium-specific evidence has accumulated over the last decade and makes the limitations of €/m² even clearer. Studies by Reusens, Vastmans et al. show that a large share of nominal house price growth between 2012 and 2021 reflects improvements in energy efficiency rather than genuine real price appreciation. In the meantime, recent work documents rapidly diverging premiums between high- and low- label dwellings. In parallel, international and Belgian research on accessibility, walkability, environmental quality and social factors demonstrate systematic implicit prices for commuting time, transit frequency, green spaces, noise exposure, crime rates and school quality, many of which are capitalized into dwelling values in ways that a single area-based metric cannot reveal. Taken together, these findings suggest that price per square meter is at best a coarse proxy for underlying value and at worst a misleading indicator of affordability and equity.

This thesis addresses that problem by constructing and estimating multi-metric valuation frameworks for the Belgian residential property. This construction is articulated around the hedonic pricing theory and spatial equilibrium models. The framework integrates measures of accessibility and commuting time, energy performance, walkability approximation, amenity access, environmental quality and social factors such as local public finance or safety. From a methodological perspective, the work combines hedonic regressions with fixed effects and quantile regression to capture distributional heterogeneity. This work also includes interpretable machine-learning techniques using gradient boosted trees with SHAP decomposition, and geographic information systems (GIS) to operationalize spatially explicit variables. The empirical analysis covers Belgian residential transactions between 2011 and 2023 and exploits recent regulatory changes, including Flemish energy labeling and the 2024 Walloon reform of registration duties, as a rich context for identifying implicit prices and their evolution over time.

The core research question guiding the thesis is:

“Are composite valuation frameworks better than €/m² for Belgian housing?”

Answering this question has implications for individual buyers, investors, developers and policymakers. For individual buyers and market professionals, multi-metric adjusted prices provide a more realistic view of total cost of ownership than raw €/m². This is even more relevant in a context of volatile energy prices, tightening renovation obligations, and heterogeneous commuting patterns. For regulators, understanding how the implicit prices of accessibility, energy and environmental quality vary across the price distribution and across Brussels, Flanders and Wallonia allows a deeper understanding of the distributional consequences of energy policies, tax reforms and transit investments. By situating Belgian evidence within the international hedonic and spatial literature, this thesis contributes to the broader debate on how to measure housing value in a way that is both scientifically grounded and operational for management and public decision-making.

2. From Lancaster to Rosen: Why dwellings are bundles, not boxes

This reflection starts from a basic question: how can demand be measured accurately to understand price movements? Lancaster defines the hedonic approach of consumer demand in an article published in *Journal of Political Economy* in 1966. Its statement is that consumers derive utility not from goods as undifferentiated wholes but from their constituent characteristics. A dwelling has various characteristics like floor area location, energy performance, accessibility, noise exposure… and its value is derived from all those characteristics. On a practical level, comparing two properties only based on their price per square meter is equivalent to assume that all non-area attributes are identical or irrelevant. In real estate market, that assumption is wrong almost every time.

Lancaster's insight was then formalized by Rosen in the same Journal in 1974. Rosen derives the competitive equilibrium hedonic price schedule (called $P(z)$) as the envelope of buyer's bid functions and sellers' offer functions, where z is the full characteristic vector. Its gradient with respect to any characteristic is the market's marginal implicit price of that characteristic. For housing those influences could be estimated through this equation: $ln\, P = \alpha + \beta_1 S + \beta_2 L + \beta_3 E + \beta_4 N + \varepsilon$, where S, L, E, and N capture structural, locational, environmental & energy, and neighborhood attributes. Malpezzi (2003) has surveyed three generations of hedonic models based on this foundation, the third one being characterized by multi-attribute panel specifications with spatial corrections. This third generation being the one used for this paper.

Alonso (1964), Muth (1969), and Mills (1967) enriched the analysis with the monocentric city models by adding to the hedonic insight a spatial equilibrium. In essence, the rent value declines with the distance to the central employment node at a rate depending on the marginal commuting cost. To make a direct link to Belgium's situation: spatial variations in €/m² across communes reflects primarily the location differential and not the difference in the intrinsic value of the built space.

This framework was then updated by Glaeser, Kolko and Saiz in 2001 to the post-industrial economy. It shows that the consumption advantages of cities have become as important as their productive advantages in driving the locative demand. This includes walkable neighborhoods, cultural density, services…

Finally, Gyourko and Tracy (1991) add up on top of this the influence of local public finance. Indeed, tax rates, service quality or fiscal capacity can be capitalized into properties values alongside other characteristics. In Belgium, where registration duties and commune-level fiscal capacity vary substantially across the 581 municipalities, the fiscal component of value is both large and spatially heterogeneous. €/m² absorbs all of this without identification.

3. Where €/m² breaks down: Theory meets Belgian evidence

As previously mentioned, at least four distinct theoretical objections to €/m² can be identified. The Belgian empirical evidence adds several more limitations. Those limitations run from spatial objections through amenity accessibility and fiscal disparities. All those general objections are supported by Belgium-specific evidence.

The first objection is spatial: The framework from Alonso (1964), Muth (1969) and Mills (1967) predicts that price comparisons across communes through €/m² are ignoring the accessibility value of the dwelling alongside its intrinsic value. The second objection is about amenity accessibility: urban areas with high amenity accessibility come with a large premium in the €/m² that is totally distinct from the space value. The third is fiscal: communes with high property taxes and better public services tend to show higher €/m². This is not because their space is intrinsically worth more but because the service & fiscal bundle is driving the demand (Gyourko, 1991). Finally, price-area elasticity in hedonic models consistently lies in the range of 0.5 to 0.8 (Malpezzi, 2003). This means that €/m² is systematically higher for smaller dwellings and lower for larger ones. This is a clear example of its contradictions.

Belgium-based evidence makes these objections more concrete. Reusens, Vastmans & Damen (2022) have shown that the value premium linked to energy efficiency has doubled between 2012 and 2021. The 7% nominal growth of Belgian house price over that decade reflects the improvement in energy efficiency of sold dwellings rather than a price appreciation. Raw €/m² trend analyses therefore systematically overstate true affordability deterioration for buyers seeking a constant quality standard. Reusens, Vastmans, Vandenbergh, van Kempen & Damen (2025) pushed further that reflection in 2025. By using CaPaKey-matched data, they documented that in 2023-2024, label-A Flemish houses were awarded premiums 9.6% above the 2016-2022 average relative to D labeled properties. In the meantime, E and F labeled dwellings fell in price. Based on that, two communes with identical €/m² medians in 2024 but different EPC average rating had completely different true ownership cost structures and €/m² could not reflect it.

A question might now arise despite these documented disappearances, why does €/m² stay a persistent reference. According to Broxterman and Zhou (2022), it is in itself informative about the market. It represents the friction in information on real estate market caused by information economics, infrequency of real estate transactions… Those conditions lead to adopt simpler representations even imperfect because adopting a more complex alternative is very demanding

cognitively and exceeds the perceived benefits. This mechanism is confirmed by Damen, Vastmans & Buyst in 2025 with the example of the introduction of EPC scores. Indeed, the introduction of EPC scores in 2008 did not change the energy capitalization, however, the color-coded labels introduced in 2019 increased the energy premium, showing the importance of the format and its “cognitive price”. A composite metric that makes alternative characteristics intelligible would, by the same logic, accelerate their capitalization into prices, which is precisely the central point of construction of this thesis.

None of these are minor qualifications. Together they constitute a strong argument that €/m² should be understood not as a reference but as a serviceable proxy easing the understanding of value differences. One that, as Belgian energy regulation tightens and the premium divergence widens, is becoming increasingly misleading and disconnected from reality. The subsequent question rising is than, what are actually the value drivers? This question will be investigated in the next section.

4. What actually drives housing value: multiple metrics, striking verdict

This section will present five different metrics that were proven to drive the value of real estate. Those metrics are from different kind from physical location and accessibility to energy performance. The goal of this section is to support the intuition with rigorous research and calculations.

4.1 Commuting costs are capitalized: The accessibility premium

Accessibility is the most studied alternative metric. It is the alternative metric with the strongest theoretical grounding and the most consistent empirical results. The logic behind it can be simplified as: improving accessibility, reducing commuting costs, raising the real wage and generating compensating willingness to pay. This improved capitalization is reflected in the rent prices studied by Alonso (1964) and called the Bid-rent mechanism. It is not a bonus in value but rather the market's assessment of the present value of years of commuting cost savings.

Debrezion, Pels and Rietveld (2007) synthesized 73 hedonic studies in their Journal of Real Estate Finance and Economics analysis. One of their conclusions was, for example, the existence of a local residential premium of approximately 2.5% per 250 meters closer to the nearest railway station. It is also interesting to note the heterogeneity across studies, from transit type to land use context or model specifications. All characteristics matter. Ryan updated the synthesis in 2022 with 46 studies from all continents. He found that service frequency is the key moderator: high frequency services generate substantially larger premiums than low frequency services. It is particularly relevant in the Belgian case, where SNCB frequencies vary drastically across cities. For example, there is a huge gap between the Brussel-Antwerp corridor and the Walloon branches. In context this means that the station alone is not sufficient to drive the value, it also requires frequent services. A dwelling 500 meters from a station served three times daily benefits from a lower premium than the one 500 meters from a high-frequency station.

Beyond the station proximity, another crucial dimension is the commuting time, which is distinct and complementary. In 2001, Rouwendal & Meijer established the marginal disutility of commuting at 40 to 60% of the net hourly wage.

Applied to Belgian interregional commuting, where rail travel from more rural communes often located in Wallonia to Brussels can add 60 to 90 daily minutes. This implies price differentials from 15 to 30% linked to commuting costs alone. Vandenbergh (2024) confirms this application

of an international framework to Belgium: communes well connected to Brussels show short time on market and smaller negotiations discounts.

On top of this, Kok & Jennen (2012) demonstrated that accessibility and energy performances have additive effects in the Dutch real estate market and that those characteristics are jointly priced. This is a concrete example that different characteristics can have their own influence, but that influence can also be a combination of factors. Enhancing the interest in this research but also making more complex.

4.2 Paying for efficiency: How EPC labels reshape Belgian prices

The theory that this part is based on is about the capitalization of future energy cost savings. A rational buyer will discount the present value of energy savings over the expected holding period. This generates a premium in price for energy efficient properties directly linked to the energy price evolution, holding period expectation and regulatory obligations. This is assessed on an international evidence base: Brounen & Kok (2011) found a price evolution of 2.2 percent per label step in the Netherlands. Hyland, Lyons & Lyons (2013) found an equivalent of 4.9% in Ireland while Fuerst & McAllister (2011) found a premium from 7% to 10% for A/B rated commercial buildings in the UK. Based on those multiple examples it can be assumed that such a mechanism is very likely to occur in Belgium.

A full analysis of the Belgian residential transaction universe linked to regional databases was conducted and published by Reusens, Vastmans & Damen in 2022. The research was conducted on the dataset of 2011 Q3 and 2021 Q2. The conclusions were that, by 2021, a B labeled house was granted a value 12% superior to a D labeled equivalent dwelling, and 22% more than an F labeled equivalent. It is also stated that approximately 7% of Belgian nominal house price growth over the study period reflected energy efficiency improvement rather than a genuine appreciation. This finding changes how to interpret raw €/m² trends over time.

However, correlation does not always imply causality. To establish it, Damen, Vastmans & Buyst (2025) used Wallonia as a control region in a cross-regional difference-in-differences design. They show that EPC score disclosure alone did not change the capitalization, the raw numerical metric was insufficiently intelligible to buyers. Then in 2019, Flanders introduced letter-based labels, which led to a material increase in the premium of energy efficient dwellings. It can thus be stated that information format shapes market capitalization. Knowing listing platforms should display energy labels prominently and not as a technical appendix.

In the January 2025 NBB Economic review, written by Reusens et al. (2025), is provided the most granular Belgian evidence to date. By using CaPaKey identifiers with EPC and asbestos certificate, they documented that the energy premium continued to increase in 2023-2024. For instance, Flemish label A houses benefited from a premium around 9.6% above the 2016-2022 average D labeled equivalents. In Wallonia, an A labeled dwellings benefited only from 4.8% increase in value. In the meantime, the renovation obligations generated a depreciation of only 2% to E/F dwellings, which is lower than expected. The explanation resides in the fact that buyers of such goods were planning renovations anyway, regardless of the regulation. It should also be noted that the study detects numerous transactions just above EPC label thresholds in both Flanders and Wallonia. It is likely that it reflects strategic misreporting by sellers or assessors seeking to avoid penalties. This non-classical measurement error contaminates naive label-dummy specifications in ways that are difficult to model without individual-level data. This would require the use of continuous EPC scores as the primary regressor alongside label dummies as robustness checks.

Reichardt (2014) was able to contextualize this gap in the sustainability framework: market's imperfections cause the market price of energy efficiency to fall below its true economic value. For the specific case of Belgium, Warisse (2022) provides a specific mechanism. Loan-To-Value (LTV) constraints in high priced areas prevent buyers from bidding up prices to reflect the capitalization of energy savings. It is estimated that the coefficients that buyers use are almost certainly lower than the true economic value of energy efficiency improvements.

4.3 The landlord's dilemma: Why energy premiums don't transfer to renters

The literature mainly focuses on energy premium for owner-occupied transactions. However, the rental market should not be overlooked. Indeed, the considerations for this market are notably different. This difference drives different pricing behavior that a single analysis cannot capture.

The main difference resides in the fact that on the owner-occupied market the buyer makes the investment in renovations and benefits directly from the resulting energy savings. The cost-benefit equation is internalized. On the other hand, in rental markets the owner makes the investment, but the tenant pays the energy bill. Melvin (2018) documented this effect based on US residential data and assessed that renters use approximately 2.7% more energy than owners of comparable dwellings. The cause of it is an underinvestment by landlords who cannot benefit from the renovation costs through a rent increase unless tenants are both aware of and willing

to pay for energy savings. Petrov & Ryan (2021) have extended that reflection to the European rental market, finding that the split incentive reduces the owner's return on renovation investment to well below the social optimum. To counter this, regulatory interventions might be necessary. The Flemish renovation obligation partially addressed it through buyer-owners but not landlords.

A recent Belgian study (Vandevyvere et al., 2025) applied SHAP-decomposed gradients[1] to dataset of Belgian sale and rental transactions from 2011 to 2016. The analysis separately estimates the energy premium in each segment and from which two particularly interesting findings emerged. The first is that the energy premium exists in both segments. However, the premium remains lower for tenants than for actual occupiers. The other learning is that more specific characteristics not formally part of the EPC rating such as heating system type, presence of solar panels, construction era… matter significantly in rental pricing in ways that EPC does not capture. This suggests that the label is a noisier signal of the real energy quality in the rental context.

The implications for this thesis are direct: owner-occupied energy premiums estimated during the empirical chapters cannot simply be applied to rental properties. This is one of the reasons why the rental market receives a dedicated section in future research.

4.4 Walkable streets, higher prices: The amenity premium

The foundation of this segment is the framework presented by Glaeser, Kolko & Saiz (2001) about consumer city: in our contemporary economy, walkable access to dense consumption amenities is a primary driver of residential demand. Based on this framework Pivo & Fischer (2011) documented a 10-point increase in "Walk-Score" was associated with a one to nine percent increase in property value. The results implied both higher rental income and lower capitalization rate, implying that walkability not only raised the value but also reduced investment risks. The equivalent for residential assets was also assessed by Rauterkus & Miller (2011) with an increase of 3000$ to 3500$ per "Walk Score".

It was also demonstrated by Li et al. (2015) that premium linked to walkability was not linear, but rather concentrated in already walkable areas (the study was conducted in Austin, TX). It was done by using a spatial hedonic specification that controls for autocorrelation. This means that adding amenities in an already dense commune generates more value than adding the same

[1] A feature attribution method to explicitly obtain coherent and objective impact of factors on a predictive model

amenities in a more car dependent location. A linear OLS specification will underestimate the premium at the high end of the walkability distribution, motivating the gradient boosting specification that captures this threshold behavior naturally.

Belgium does not have “Walk Score” data directly available for communes. To create a proxy to estimate Walk Scores in Belgium, another research could reside in a combination of OpenStreetMap data and Pivo & Fisher's (2011) implicit weighting matrix to measure the density of points of interests (POIs) within 1km of each communes’ centroid, then weight them according to their category. A similar POI-density approach was validated by Trojanek, Gluszak & Tanas (2018) for use in Warsaw as a more appropriate reference from Europe than US-centric studies. Their research revealed that a green space premium of 2.8% to 3.1% existed for all buildings constructed prior to 1989, while that premium increased to between 8% and 8.6% for new construction after 1989.

4.5 Green views, quiet streets: Pricing the environment

According to Freeman’s (1979) hedonic valuation framework for non-market goods, environmental quality is characterized by three distinct dimensions. The first one is the proximity to green space which drives the prices up. Tyrväinen and Miettinen (2000) found that forest views drive up the value of a dwelling by approximately 5% in Finland, with a direct link between distance and value for urban proximity of green area. Arentze (2024) demonstrated that GIS computed multi distance band green space variables outperformed simple proximity. That spatial autocorrelation correction is necessary to obtain unbiased estimates. This point showcases the spatial robustness of GIS variables construction.

Noise pollution has on the other hand a quiet and coherently negative impact on prices. This effect was analyzed by Nelson (2004). He concluded that, for example, dwellings were suffering from a 0.58% depreciation per decibel for aircraft noises across 23 airports. For road traffic noises, Nelson (2008) found a depreciation of approximately 0.4% per decibel. Andersson, Jonsson & Ögren (2010) conducted simultaneous research on road and railways to showcase the different impact of noise sources. For instance, their results show that for roads the negative impact is between 0.5% and 0.7% while for railway its rather between 0.3% and 0,4%. Therefore, those specifications must be calculated separately for hedonic specifications. A Belgian specific case application could be the Flemish Brabant which has its value driven by a high accessibility premium (thanks to the ring) but also suffers a discount linked to the Brussels’ airport flight paths that generate aircraft noises. In this case only a multi-metric

framework can decompose the value drivers and therefore be more precise than the €/m^2 metric, which can lead to misleading conclusions.

The final dimension is the air quality. For example, the industrialized zones such as Antwerp port or the Hainaut-Liège corridor support heavier particle concentrations which can imply discounts of up to 5% in affected communes (Chay & Greenstone, 2005). This information also showcases that the Flanders-Wallonia price divergences that are visible with €/m^2 measures are not only driven by accessibility disparities, but also by environmental mechanisms.

4.6 Taxes, schools, and safety: The overlooked value drivers

As a reminder, Gyourko & Tracy (1991) demonstrated that local public finance, such as tax rates, public service quality… are capitalized into dwelling's value. In Belgium, the registration duties can vary from 3% for first time buyers (following a Walloon reform in Nov-2024) to 12.5% for investors. In the meantime, communes' fiscal capacity varies enormously, which makes the fiscal component of property value both large and rapidly evolving. The Walloon reform, for example, is expected to have driven the transaction volumes in early 2025. This creates a shock that requires appropriate analysis in the regression.

Communal crime rates can be assessed thanks to annual reports published by the federal Police. It has a negative effect estimated between 0.1% and 0.5% per percent increase in crime rate (Thaler, 1978). School density, healthcare access and local park coverage are included as tier 2 social metric variables. These characteristics have not yet been conclusively proven to have a direct impact. However, it is plausible that communes with good amenities, lower crime and better schools also tend to attract buyers that are more willing to pay a premium for efficiency or accessibility. This creates a correlation to the market value.

Differences exist between the communes, but what characterizes Belgium are it's disparities between the linguistic regions leading to cultural and geographical specificities which will be studied in the next section.

5. Three regions, three logics: Why Belgium is a natural testbed

Belgians have a reputation for often owning their homes, this reputation is confirmed by the data provided by Eurostat (2026): with an owning rate of around 70%, above the EU average of 68%. This implies that most Belgian households have to face the difficulty of making a major financial choice about the property they will own. As it is documented by Warisse (2022), Belgian household wealth is heavily concentrated in real estate with a share of wealth ratio around 41%. It also known that owner-occupiers have longer planned horizons than tenants, they are more likely to fully capitalize the present value of previously mentioned characteristics (energy savings, accessibility benefits, environmental quality…) in their willingness to pay. This owner-occupier's dominance has a direct impact on the research conducted in this thesis. Indeed, the preferences on the market will reflect the tendency for rather long-term horizons when choosing a house.

The recent (2022-2024) economic situation was unusually eventful. The first key factor was the rapid increase in loan rates: rising from near 0% to 4% between 2022 and 2023. This combined with a continuous high inflation rate, has produced a price correction estimated to reach up to 11%, despite the nominal prices remaining positive (ING economics, 2023). In the meantime, mortgage issuance dropped significantly: 45% fewer mortgage loans were granted in January 2023. However, the NBB (National Bank of Belgium, 2023) notes that Belgian banks limited the pass-through to mortgages partly thanks to longer loan maturities. Recovery was faster than expected: in 2025 transaction volumes rose by 21% compared to the previous year and mortgage loan applications rose by 15%. This was driven by stabilization of the rates and a restored confidence for buyers (European Mortgage Federation, 2025).

This macroeconomic context has 2 distinct implications for this study. The first one is that between 2022 and 2024 it was witnessed an acceleration of EPC premium divergence. This is due to multiple factors: volatile energy prices (with high spikes), increasing awareness around the running cost of a house and the integration by the banks of the EPC in their calculations to approve mortgages. Indeed, the EMF (European Mortgage Federation, 2025) documents that loan applications with good APC score are now explicitly considered as less risky for Belgian banks. The second was the Walloon reform on registration duty done in the end of 2024 (Gouvernement Wallon, 2024). By cutting the rate for first time buyers from 12.5% to 3%, the consequence was a demand shock in 2025 that must be considered to fully understand the evolution in time and the evolution through regions.

The study across Belgium's different regions is particularly interesting. Despite the share of common macroeconomic variables such as NBB rates, similar labor market conditions and national mortgage regulations. Other particularities are unique to some regions and linked to the previously mentioned value drivers. For instance, Brussels centralizes employment accessibility and amenity density. Flanders has highly energy efficient dwellings thanks to earlier and stricter regulations. Finally, Wallonia falls behind on previously mentioned aspects but benefits from a more attractive tax framework. These differences are external from the perspective of a hedonic analysis and thus can be exploited to better understand the influence of each factor.

On a micro level, an excellent complement is provided by Vandenbergh (2024). His analysis depicts that communes with strong characteristics show short time on market and smaller negotiations discounts. This is consistent with a strong and homogeneous buyer demand resulting in rapid transactions. On the other hand, communes where non-size-related characteristics are harder to evaluate show an opposite tendency. This friction in information is made visible by transactions data. A way to compensate this lack of information would be alternative metrics, that give a better understanding, more explicit and measurable. This is precisely the aim of this thesis.

The commercial real estate evidence provided by Kok & Jennen (2012) provides a methodological template. It was done by simultaneously estimating energy and accessibility premiums on a single hedonic regression based on the Dutch office rents. They found that both metrics had positive impacts and those impacts were cumulative. This additivity supports the idea that a multi-metric calculation can approximate the value of a dwelling.

6. Putting it together: What the evidence says about €/m²

This first part comes to an end and set out whether price per square meter is an adequate measure of Belgian residential real estate value. Or whether a multi-metric framework incorporating accessibility, energy performance, walkability, environmental quality and social factor is able to capture more accurately the value drivers of dwellings.

The core problem is that €/m² has numerous limiting implicit biases: it assumes that all non-area related characteristics are identical and does not have influence on the final value. That assumption is contradicted by the hedonic theory (Lancaster 1966, Rosen 1974) and other Belgian specific evidence. As a counter example, Reusens or Vastmans et al. show that a large share of Belgian house price growth between 2012 and 2021 reflects energy efficiency improvements rather than a genuine price appreciation. The premiums for high versus low energy labelled dwellings have continued to diverge sharply through 2023-2024.

The research is also grounded on other foundation than hedonic theory. It also relies on the monocentric city and spatial equilibrium models of Alonso, Muth and Mills and the consumer-city and fiscal capitalization insights of Glaeser, Kolko, Saiz, Gyourko and Tracy. Brought together these theories establish that location, accessibility, energy performance, amenities, environmental exposure, and local fiscal/service quality are all capitalized into price, none of which €/m² can isolate.

Belgium is an ideal testbed for the research: Belgium has a high homeownership rate (around 70%) and a heavy concentration of household wealth in real estate (about 41%). But the most interesting aspect is its three distinct regions: Brussels' accessibility density, Flanders' stricter energy regulation, and Wallonia's more favorable tax framework. Those differences create natural variation allowing the isolation each metric's implicit price.

When considering the central claim of this thesis, this literature and evidence base support it entirely: €/m² functions as an “easy to use” tool but economically incomplete and hiding numerous other variables. In the meantime, a composite multi-metric valuation framework offers a more accurate, equitable, and policy-relevant measure of Belgian residential property value but is more complex to understand.

Part 2: Interrogating my own framework: Critical reflections on method and meaning

7. From a simple doubt to a multi-metric framework: my research journey

This section is going to be different from the previous one. It is an honest attempt to explain the work behind the research previously stated and how that result was obtained. This includes wrong turns, surprises, and moments where paper or datasets required me to change my approach or to adapt my expectations.

7.1 The starting point

This research did not start with an explicit question, but rather with suggestions and discussions with my thesis supervisor. The original interest was to investigate alternative metrics, but the exact subject was not defined yet. After thoughtful discussions we ended choosing real estate, a widely studied subject with implications for everyone, measured with a very reductive metric: €/m². It came quickly to our mind that this metric was very reductive and could not represent the deepness and all the specificities of the real estate market. The original thought sounded like: “Properties in different locations, different energy profiles etc. could have the same value in €/m² and thus be compared, while they had in fact many differences and not meant for the same persons.”

At first, instinctively, I started to ask myself if it was simply possible to improve €/m². But that question was too vague: How? Relative to what? For whom? How to assess the improvement? This required a first round of reading to take a first picture of the documentation available and its different subjects.

After reading the works of Lancaster (1966) and Rosen (1974) my approach of the problem changed. Instead of thinking that €/m² was just a bad proxy, I understood that it was rather a theoretical misspecification and a global simplification of the market to make it more accessible. It only controls one attribute in the middle a multi-attribute equilibrium. Once I understood that, the question shifted from “how can I improve €/m²?” to “What does the theory predict about the evolution of €/m² if variations are introduced?” That shift of approach was the first real step to deepening the research and better understanding the subject.

7.2 The surprise: Belgian well-developed literature

The second milestone in my research was discovering the density and the quality of literature specific about Belgium. I expected a few NBB working papers or research conducted by the different regions. But instead, I had the pleasant surprise to find systematic rigorous research programs spanning over years.

Reusens, Vastmans & Damen (2022) studied the premium of EPC labels across the full transaction universe between 2011 and 2021. In parallel Damen, Vastmans & Buyst (2025) ran a cross-regional natural experiment. Also, in January 2025 the NBB published a paper written by Reusens et al. (2025) documenting the divergence of price post the renovation obligation. It was done by using individual CaPaKey data, including findings that required me to revise my empirical approach.

Indeed, this forced me to redesign my research approach. My initial approach was to replicate hedonic methods to Belgium datasets. But the NBB had already done it in a very qualitative way. I then entered a questioning of how I could still contribute to the existing literature by identifying a gap in the existing literature. The answer was to simultaneously estimate multiple alternative metrics, exploiting the regional differences as natural experiments, analyzing the price distribution rather than the mean and imagining buyer adaptative composite indices. The five research gaps identified in the 12th section are not proof of laziness or insufficient work. They emerged from thoughtful analysis of the existing literature about the already covered subjects.

7.3 The methodology

My methodology followed the logic given by the data, the other way around was not manageable.

I started to study the OLS hedonic regression, this was an obvious starting point given that it was the most theoretically grounded, and that I had already the opportunity to work with such regressions previously. Then I started to get interested in quantile regressions when I used the work of Zietz, Zietz & Sirmans (2008). This allowed me to better understand the heterogeneity of implicit prices across the price distribution. Thanks to this method I was able to understand the consequences of policies such as renovation obligations and their distributional consequences. This was not measurable with OLS averages. Machine learning was then incorporated following the lecture of Lorenz et al. (2023) that demonstrated that attribute-price

relationship matter for coefficients estimates because of their large enough nonlinearity. The SHAP framework solved one of my main concerns when starting the research: the interpretability of the data gathered.

The latest significant change I had to implement came from the bunching findings in Reusens et al. (2025). My original empirical approach used EPC label as the primary energy variable. However, I understood that strategic misreporting near label limits (agglomeration near the lower band of each level) contaminates label specifications, inducting non classical measurements errors. Therefore, I had to switch to continuous EPC scores as primary specifications and with labels as robust checks. This really challenged all the understanding I thought I had built and really questioned the pertinence of my whole work. The learning I took from this bad episode was that empirical strategy must respond to data quality findings.

7.4 What I changed my mind about

My original thinking before starting this thesis was that the three Belgian regions would show similar hedonic prices with little variations due to regional specificities. For me regional heterogeneity was about to be a nuisance to control rather than a central analytical asset.

Due to the NBB evidence that assumption quickly changed. The clear gap appearing between Flanders and Walloon’s premium for EPC (Reusens et al., 2025) shows to which extent the energy premium is a regional variable rather than a national constant. The Walloon registration duty reform from December 2024 adds a fiscal discrepancy at the same moment as the renovation obligation which generates an energy premium divergence. Belgium's regions are not just different contexts for the same analysis. They are the core foundations of the analysis.

8. Choosing the right lens: A multi-method strategy and its trade-off

After using the numerous theories in the first part, it is also necessary to clearly understand the specificities of each method studied, its strengths, weaknesses, and possible biases.

8.1 The workhorse model: Strengths and blind spots of hedonic regression

Description

The mention of hedonic regression comes multiple times in the previous section, but how is it exactly built? It can be realized following the third-generation specification of Malpezzi (2003). This includes structural controls, locational and accessibility variables, environmental and energy characteristics and neighborhood socio economic controls. All this is in a log linear form with commune and year fixed effects. The period studied spans from 2011 to 2023.

Fixing the commune absorbs unobserved time invariants in commune heterogeneity. Those factors are usually the accumulation of historical, cultural and institutional factors that are difficult to measure directly. Fixing the years on the other hand absorbs the temporal shocks including the 2021-2022 energy price peak and the 2022-2024 low-interest rate cycle.

The spatial autocorrelation is addressed by the model of Anselin (1988) about spatial lag and model errors. Supported by Arentze's (2024) demonstration that corrections are necessary for unbiased spatial estimates when unobserved neighborhood quality drives both the metric variables and prices simultaneously.

Strengths

Hedonic pricing appeared to be the most theoretically grounded method available, with a direct connection to Rosen's (1974) framework that served as a basis for this thesis. It implies many advantages: it is reproducible, interpretable and benchmarkable against the literature (Reusens et al. 2022, Reusens et al., 2025 and Damen et al.,2025). Fixing the communes effects gives a credible identification reference. The log-linear form is the standard in the EPC premium literature. Allowing direct comparison of Belgian estimates against international benchmarks.

Weaknesses

There are four identified limitations to this method. The first and most important is the commune level unit of analysis. Indeed, using commune medians rather than individual transactions introduces measurement error that biases coefficients toward zero. This was mentioned and demonstrated by Reusens et al. (2025) by comparing individual level and aggregated EPC estimates, showcasing those individual results are substantially higher. The

interpretation of the commune level analysis should then be that it is a conservative lower bound on the real influence on prices.

The second limitation is endogeneity. Indeed, transit investment follows existing demand, and the walkability is a response to purchasing power. This generates reverse causality that the effect of fixed communes can only partially absorb. Using instrumental variable strategies with railway network topology can be considered as solid checks.

The third limitation is the EPC bunching. Reusens et al. (2025) have identified strategic misreporting of EPC label related thresholds, contaminating label-dummy specifications and requiring continuous score variables as the primary regressor.

Finally, the omission of quality. Better EPC rated properties tend to have better unobserved quality, which may inflate the energy premium estimate. Structural controls partially address this but cannot fully resolve it without an individual property fixed effect.

8.2 Does value depend on where you stand? Testing for heterogeneity through quantile regression

Description

Quantile regression introduced by Koenker & Bassett (1978) and further reviewed in the housing context by Zietz, Zietz & Sirmans (2008) estimates conditional quantile functions by minimizing the weighted absolute deviation. Applied to the Belgian market dataset it reveals whether implicit prices of accessibility, energy and walkability are homogeneous across the price distribution or differ between affordable and expensive communes.

Strengths

Giving interest to distributional questions has a direct implication for policy relevance. For example, if the energy premium has the largest importance for houses at the lower end of the price distribution, due to the larger importance of running costs for financially constrained buyers, this informs regulators who the renovation subsidy is targeting. On the other hand, if accessibility premiums are larger for dwelling for dwellings at the top of the price distribution, because wealthier buyers can afford to be more selective with well transit served locations, this identifies that investment towards transit will benefit them. Simple OLS averages cannot answer these questions.

Weaknesses

Quantile regression does not solve the endogeneity concerns affecting OLS, it carries the same omitted variables as the one mentioned in the previous section, this time they are just disaggregated by price level. With just over 580 communes and multiple studied years, it is expected that extreme quantiles will be estimated with limited precision. The interpretation of multiple coefficients vectors requires care, to avoid over interpretation of noise at the extremities of the distribution.

8.3 Letting the data speak: Machine learning without the black box

Lundberg & Lee (2017) introduced gradient boosted trees (XGBoost) with SHAP decomposition. It was then applied and validated to real estate analysis by Lorenz, Willwersch, Cajias & Fuerst (2023). It provides a complement to the predictions made by hedonic regression. SHAP method assigns values to each feature: the average contribution to the predicted price across all possible features ordering, allowing to capture non linearities automatically.

In their research, Lorenz et al. (2023) discovered that fitted trees using gradient boosting decrease the overall RMSE outside of the sample by around 25% compared to linear regression through OLS for hedonic models, and that the importance rankings from the SHAP method are similar to those from the hedonic coefficient determinants. An example of how this finding relates to the average Belgian rental market is illustrated with an analysis of data from Belgium's rental market.

The characteristics that are not explicitly measured by the EPC (type of heating system, type and number of solar panels installed on the property, age of the construction) have significant pricing effects beyond what would have been estimated using an OLS regression.

Strengths

This method captures automatically non linearities and high order interactions without parametric constraints. This is particularly useful given the documented nonlinearity of the walkability premium (Li et al., 2015) and EPC label threshold effect (Damen et al., 2025 and Reusens et al., 2025).

Weaknesses

This method does not resolve causal identification: gradient boosted trees learn predictive associations not causal effects. Therefore, the hedonic OLS with fixed effects remains a

preferable causal estimator, while machine learning is a predictive complement and a non-linearity detector. An example of risk situation is Brussels: with only 19 communes it requires a careful cross validation to avoid overfitting.

8.4 Mapping value: Spatial data as a missing ingredient

Building a GIS showcases all the spatially defined variables that are measured. For transit proximity it uses haversine distances and OSRM routing from commune centroids to SNCB station locations that were extracted from GTFS feed. For green spaces coverage in uses the Copernicus Urban Atlas with multiple buffers following Arentze's method (Arentze, 2024). To measure noise exposure, it uses EU noise maps. There is a difference for road, railway and aircraft noises to follow Andersson et al. claims (Andersson et al., 2010).

The main limitation of GIS is the commune centroid simplification, indeed, within commune spatial heterogeneity is averaged, inducting measurement errors that biases accessibility and noise coefficients towards zero, and underestimating individual level premiums.

8.5 From coefficients to decisions: What this means for buyers, investors, and regulators

For individual buyers:

Hedonic analysis has been used to estimate the implicit or hidden value of each alternative metric (in euro terms). For example, a buyer comparing two communes with the same €/m² but with different EPC profiles, transit accessibility and noise exposure is deciding between two different total cost of ownership profiles. The composite indices developed in this research allow for quality-adjusted comparisons of these two different total costs of ownership profiles. Where there is a first-time buyer restricted to a Loan To Value level that is in a high-accessibility area, the accessibility premium has the potential to be redefined. For instance, the €/m² premium reflects the capitalized commuting cost savings that will at least partially reduce the purchase price over the holding period.

For investors and developers:

By investigating quantile regression, those actors can reveal the premiums linked to each metric: dwellings with high energy performances and good connectivity will allow them to make the largest return on investment. The sustainability gap identified by Reichardt (2014) suggests that energy efficiency is undervalued in lower market segments, which creates a potential renovation arbitrage opportunity. On the other hand, the study about energy efficiency

on the rental market (Vandevyvere, 2025) shows that owner-occupied premium does not translate directly to the rentals segment, where the split-incentive problem generates different dynamics that this thesis could not resolve.

For policymakers:

The growing premium related to EPC labels is not a costless market efficiency. It is rather a distributional outcome with equity consequences. Concretely, if the premium falls harder at the lower end of the price distribution, the renovation obligation will implicitly create a segmentation in the market where buyers that chose efficient dwellings capture the premium while buyers that opted for less efficient dwellings face rising hidden renovation costs. Walloon reforms about registration duty in December 2024 are already reshaping the transaction cost landscape. Multi-metric adjusted prices are a tool capable of tracking these distributional consequences in real time, which €/m² cannot do.

9. Does the data match what we would expect? Confronting results with intuition

This section is probably the one I hesitated the most to write. Indeed, traditional academic works present their results as they were known from the beginning and as the researcher always knew what question to ask and always expected the answers they got. Here I would like to act differently. I want to showcase the evolution of my perception about the subject, and through this path give a better understanding of the real estate market. Following this path allow to better understand the challenges faced by the people working about this topic and give the reader a better comprehension and appropriation of those challenges.

My intention is also to bring more than simple numbers and affirmations, but also enhance them with simple examples that allow the opening of a deeper reflection. Indeed, the hedonic model is elegant and the Belgian evidence on EPC premiums or accessibility gradients are rigorous. However, a neighborhood is not a regression, or a set made of observable covariates. In the meantime, the people buying, selling in the studied properties carry with them memories, aspirations, identity and social networks that no hedonic coefficient fully measures. By understanding where my original intuition was naïve or wrong will allow me to go beyond econometrics and capture the sociological complexity.

9.1 Where it started: the map I wanted to draw

When I started my research, I needed a first objective. At that moment my objective was to create a map of Belgium at commune level with the price variations. It would have been than possible to get the split of the characteristics having an influence on the value: so much for the location, so much if the EPC is A... A kind of valuation dashboard that would replace the blunt instrument of €/m² with something more informative, easy to understand and more honest. In an utopic world this map could even allow finding gaps in the market or predict at what price a house should be sold anywhere in Belgium.

In the beginning that ambition did not feel unreasonable. The data seemed in principle to be available: Statbel publishes transaction prices, the regional energy agencies publish EPC distributions, the SNCB publishes GTFS data, OpenStreetMap covers the entire country… At that moment I thought I had sufficient diversified data to build my hedonic model. All I had to do was to assemble the dataset and then the rest would follow.

I was all wrong… what I underestimated badly was the gap existing between data availability and identifying rigorously causal relations. As an example, having data on EPC ratings and

property prices for the same commune does not tell you what portion of the value was brought by the EPC rating. Indeed, properties with better ratings tend to be newer, better located and better maintained in ways that are not directly observable. The literature already tried to tackle the problem for 20 years before me. Reusens, Vastmans and Damen (2025) and Damen, Vastmans and Buyst (2025) were able to resolve that very recently by exploiting Belgium's regional policy divergence as perfect natural experiment setting. The first learning I made in my research was thus that in order to build a reliable valuation tool, you need to understand what you can and cannot claim to know about each variable's causal contribution. That understanding, it turned out, was the thesis.

9.2 The first obstacle: value is not objective

My intuition was quickly challenged following the reading of Lancaster (1966) and Rosen (1974). Indeed, my original assumption was that dwelling's valuation was something close to objective: a well-designed model could, in principle, identify the real value of each property by getting rid of irrationalities, exceptions and parasite noises. The hedonic framework partially corrected this assumption without fully replacing it. Rosen's model is not a theory of objective value but rather a theory of equilibrium prices: the prices that emerge when buyers with heterogeneous preferences and sellers with heterogeneous costs interact in competitive markets. As a concrete example we can take the hedonic coefficient on EPC ratings. It doesn't tell you the true value of energy efficiency. It tells you the market's average marginal implicit price of energy efficiency at the current equilibrium, which depends on the current distribution of buyer income, the current level of energy prices, the current awareness of the renovation obligation, and dozens of other factors that shift over time.

The distinction between equilibrium price and objective value is more than a simple detail. It means that the valuation map I was imagining building was not map of "value" but rather a "representation of the current market equilibrium with its very specific attributes" that will be different in a matter of weeks or months. A proof of that is the EPC premium that nearly doubled between 2012 and 2021 according to Reusens et al. (2022). This evolution kept its trend in 2024 according to the NBB study. This is the proof that a map would need to be redrawn at least every year not because the dwellings changed but rather because the market's assessment of the different characteristics is continuously evolving.

9.3 The sociology of location: what the hedonic model cannot see

The second challenge my intuition faced was a deeper one: how can I consider what the hedonic model cannot measure and why aren't they measurable? My original representation treated

locations as bundles of observable characteristics: distance to a train station, proximity to a park, noise exposure… What I gradually understood was that in fact location where, perhaps, primarily social facts. Neighborhoods have reputations and histories that are not reducible to measurable attributes. They carry connotations of class, ethnicity, aspiration, and stigma that shape demand in ways that persist long after the objective characteristics change.

The sociologist Bourdieu (1989) presented a framework that tries to understand that persistence. According to his theory of social space, physical space is always simultaneously social space. This means that the distribution of agents across geographic positions in fact reflects and reproduces the distribution of capital (from economic to social and cultural capital) across the social position. The location in which you live is more than just a location, it's a statement about who you are and who you aspire to be. An example of that is the gentrification: the process through which a previously low-status neighborhood acquires new social meaning as higher-income residents move in. This gentrification effect can have a huge impact on prices without any change in the observable physical characteristics of the dwellings. The hedonic model will attribute these changes of price to time fixed effects or to unobserved quality improvements. Therefore, the representation of the social space, and the symbolic capital is one of the characteristics that the hedonic model is not able to capture.

To apply this theory to Belgian specific examples we can use the communes of Molenbeek and Saint-Gilles in Brussels. Both communes have faced a gentrification despite a persistent stigmatization from media and political discourse. This created a situation where objective measures of neighborhood quality (access to transit, proximity to amenities, green space...) would predict higher value than what is actually observed, this was due to the social meaning attached to those places that the hedonic model is not able to capture. The effect of gentrification would have stayed unexplained with an only hedonic perspective. On the contrary communes such as Tervuren or Overijse have prices well above what their objective characteristics would predict. This is partly due to their social reputation and the prestige of those locations. DiPasquale and Wheaton (1996) in their standard treatment of urban economics, acknowledge that location value reflects both measured attributes and unmeasured reputation effects, but the profession has not yet developed satisfactory methods for separating the two.

9.4 The emotional economy of homeownership

My intuition about the rationality of a model about real estate market was also challenged by another sociological reality. This challenge finds its roots in the fact that buyers identify their

preferences, gather information about available properties, compute expected utility for each option, and choose the bundle that maximizes utility subject to their budget constraint, but there exists a substantial friction in information. This phenomenon was studied by Broxterman and Zhou (2022) showing that information is not freely available and that buyers make systemically different choices depending on what they know. But the sociological reality is even more disruptive: for most Belgian households, buying a home is not primarily an exercise in utility maximization. It is an exercise in identity construction.

This observation is not only a marginal phenomenon: the home ownership rate of around 70% (Warisse, 2022) in Belgium reflects not just a financial preference for owning over renting but rather a deeply embedded cultural perception of what a responsible adult is, a successful professional or a good parent. The Flemish concept of “eigen huis” (meaning “own house”) carries a strong weight of meaning that is not captured by any attribute in a hedonic regression. It explains numerous behavior that purely rational models cannot explain. It explains, for example, why Belgian buyers tend to systematically stretch their budget beyond financial advisor’s recommendations. It can also explain why buyers prioritize detached houses over apartments even when the financial case for apartments is stronger or the tendency to resist downgrading in the face of adverse life events in ways that a purely rational model would not predict.

These disparities with rationality are not only observable in Belgium with its specific culture. Behavioral economists have documented several other surprising results. Case and Shiller (2003) showed that housing market actors tend to hold extrapolative expectations, believing that recent price trends will continue even without any fundamental reason to do so. This generates boom and bust cycles unexplainable with a hedonic model. Another striking observation was made by Genesove and Mayer in 2001about the loss aversion on housing market. Indeed, sellers whose homes have declined in value relative to their purchase price set higher asking prices and wait longer for buyers, generating downward price rigidity during corrections that slows market clearing. Finally, Ariely, Loewenstein and Prelec also showed in 2003 that the “asking price” deeply influences the buyer’s willingness to pay, independently of the objective value of the good. This not negligible influence is also not estimated in the hedonic model that only considers the final transaction price.

What all those considerations mean for the map I wanted to draw is that even if I measured every objective attribute and even if I perfectly estimated the hedonic price gradient for each

attribute, I would still be displaying only a part of the observed variation. A non negligeable part of the buyer's willingness to pay in fact represents emotional attachment, social aspiration… that is unique to every actor. The key learning I retrieve from this reflection, is that the market I wanted to study goes well beyond an objective value optimization. It is in fact a mirror of the social image influenced by its origins, its current situation and its aspirations for the future. All those aspects are unique to every buyer, and a map would not be able to reflect this unicity.

9.5 What I did not see coming: the politics of energy

The finding I was expecting the least and that I could not predict before studying the subject is the following: the political and distributional dimension of the EPC premium. In my mind, energy performance was a technical characteristic based on objective and 100% reliable measure such as insulation thickness or heating system type. However, the literature has taught me that in a market, like the Belgian real estate market, price is actively shaped by regulatory interventions. Those interventions have distributional consequences across income groups and regions, and that transparency is complicated by deliberate strategic misreporting.

The best illustration of this phenomenon is the article written by Reusens, Vastmans, Vandenbergh, van Kempen and Damen in 2025. When the Flemish renovation obligation (requiring buyers of E and F-rated properties to reach label D within five years) came into application in January 2023, a portion of sellers, or their EPC assessors, responded by reporting lower energy scores than the one previously measured rather than starting renovations. This created large groups of dwellings just above the label threshold values. This wasn't linked to any measurement errors, but rather linked to a behavioral response to a policy that has stakes high enough to motivate falsification. This observation means that the value the market allocates to energy efficiency is not a simple reflection of buyer's preferences and seller's cost but also a strategic incentive linked to regulatory design.

In this case the sociological implications are important. Indeed, the renovation obligation will benefit some people and affect negatively some others. The distribution of those persons is not random, instead the delimitation between those two roughly correspond to existing wealth and housing quality gaps. To picture that simply, this means that rich Flemish owners with recently renovated homes see the value of their assets rise thanks to the increasing premium. While poorer owners with ageing houses and that could not afford renovations face a combination of higher energy costs and the lowering of their asset value because poorly isolated houses are less attractive. Case and Shiller (2003) observed that housing markets tend to amplify

inequalities rather than moderating them. This example about renovation obligation is a striking example despite its original intention of a better environmental impact and its expected mechanism that would transfer value from lower-income households in energy-inefficient dwellings to higher-income households in efficient dwellings. My original intuition had not included a distributional analysis. The literature made it unavoidable.

9.6 The limits of data: the unmeasurable

The final lesson I learned from my research and that I find both reassuring and humbling. This lesson is that the most important determinants of what a property is worth to the people who buy dwellings is unmeasurable and different for every buyer.

Let's dig into the "happiness of a neighborhood". What is meant by that is the quality of relationships between neighbors, the security feeling, the trust and knowledge in local institutions such as bakery, school, … All this information is not captured in the data I assembled. The social psychologist Robert Putnam showed in 2000 that in Italy, "social capital" (the density of civic associations, the degree of interpersonal trust, the norms of reciprocity that prevail in a community) is a powerful predictor of institutional performance, economic prosperity and life quality. In a linked study conducted in the USA Putnam documented that communities with higher social capital are more resilient, healthier, and report higher subjective wellbeing. None of this is measured in a hedonic model, but it is almost certain that it shapes property demand. People want to live in communities they trust, where the feel known and where there is a fabric of informal social life beyond the individual dwelling.

This information is not a fundamental weakness to my research but rather a call to modesty. The multi-metric framework developed so far is by far more informative than the €/m², capturing real, quantifiable sources of value that the single ratio occults. But it is not a complete theory of housing value. It is an improved measure applied to the observable portion of characteristics of a market that is fundamentally linked to subjective and objective social aspects. Kahneman and Tversky (1979) studied the psychology behind judgment under uncertainty and it can be applied to our case. We tend to rely most heavily on the attributes we can measure, precisely because they are measurable, regardless of whether they are the ones that matter most. The energy label is legible; the warmth of a community is not. My map would have been a map of the legible portion of value. That is worth building. But it is important to know what it is and its limitations.

9.7 What I learned: a different kind of map

While reaching the end of this work, I could still build a map, but my objective and the way of building it has drastically changed since the start of the research.

As a reminder, the original map intended to get back a precise valuation with each component cleanly identified based on the location and the asset's characteristics. This would have been a map of answers. Now that I have deeper knowledge on the subject, the map I would build is totally different, and build a map of questions: which communes score well on measurable alternative metrics, which score poorly, and where the gap between €/m² and multi-metric quality-adjusted value is largest. That gap would be interesting to investigate because it points to where the information friction is, where social reputation effects and behavioral biases are creating the largest misalignments between what buyers pay and what they are getting.

Let's shift from theory to illustrative example: the communes in Walloon Brabant that border Brussels (such as Waterloo, Braine-l'Alleud, La Hulpe…) combine reasonable EPC scores, decent SNCB connectivity, lower registration duties than Brussels, access to both Walloon nature and Brussels' job market. Yet there the €/m² metric of that region remains below the €/m² in Flemish Brabant communes, despite them having comparable or weaker objective characteristics. How can we explain this gap that must be caused by unmeasured characteristics? Is this a genuine value difference that reflects unmeasured quality gaps in Walloon versus Flemish communes? Is it partly a reputation effect and partly a linguistic community sorting dynamic that the hedonic model cannot distinguish? The boundaries created by language communities have been studied by Arbaci in 2019. He studied multiple cities in Europe and concluded that in Belgium, language communities acted as partial barriers to residential mobility, generating price differentials that do not reflect any objective quality difference. This dimension is not assessed in the multi-metric valuation making it incomplete, despite being more exhaustive and precise than €/m².

On similar way, Flemish coastal communes such as Knokke-Heist, De Panne or Middelkerke, report very high €/m² premiums that reflect a specific combination of amenity value (sea proximity, dune landscape, recreational infrastructure) and investment demand (second homes, holiday lets). Applying the hedonic model becomes difficult and is seriously questionable. The buyers in the secondary home market have fundamentally different preference profiles from primary home buyers elsewhere in Belgium. This means that applying a single national hedonic price schedule to both markets is likely to produce coefficients that are wrong for both markets. In the research conducted by Case and Shiller in 2003, it was concluded that the secondary

home markets amplify price cycles relative to primary markets. The Flemish coastal market is a clear illustration of that phenomenon. To reach my goal of building an exhaustive map I would need to make a market segmentation between primary and secondary houses. That segmentation requires first acknowledging that 'the Belgian housing market' is itself a convenient fiction that conceals at least three or four structurally different sub-markets.

9.8 Maturity as a researcher: from confidence to calibrated uncertainty

I want to finish this section with a more reflective part about my position in conducting research, and the process through which my thesis changes what I believe it means to understand a complex subject.

When I got started, understanding meant knowing the answer. I wanted to understand the valuation mechanism in Belgian real estate market. I knew numerous mathematic tools to approach a solution with formulas and proven theories. My vision was such that if I can assemble the needed inputs, I will be able to produce qualitative outputs. My thinking is now that framing was always wrong for complex social phenomena, not just for the specific subject I studied.

After all this work my perception of property value has changed, it is not a physical constant waiting to be discovered. It is rather an equilibrium of millions of individual decisions and preferences made under uncertainty. Those decisions and preferences are shaped by regulatory interventions that create winners and losers, all this colored by emotional and symbolic dimensions that economics has only begun to model seriously. Rosen’s hedonic framework (1974) appears to be the best available tool for recovering the observable portion of that equilibrium. This tool, however, is not sufficient to capture the complexity of the real estate market. Sociological literature, such as Bourdieu on social space (1989), Putnam on social capital (2000), Genesove & Mayer on loss aversion (2001) or Case & Shiller on extrapolative expectations (2003), is not complication that makes economist’s job harder. It is a part of the knowledge necessary to understand human behavior that any serious analyst of real estate markets needs to take into consideration.

The final learning I made during this research work is that, as researcher, you need to be comfortable with uncertainty. It is important to know precisely what you can claim, why you claim it and where the boundaries of your knowledge lie. When thinking about my original idea of building a map, the one I can now build is more limited than the one I originally imagined. It is also, I believe, more honest and therefore more useful. A map that ignores or

hide its own imprecision is worse than no map at all, because it gives false confidence to the people who rely on it. A map that is transparent about what it measures and what it does not is the foundation for genuine improvement over time.

That, perhaps, is the most important thing this thesis taught me: not a set of coefficients, but a way of thinking about the relationship between models and reality.

10. What this thesis cannot claim: Data, identification, and scope

Finding and acknowledging limitations in its own work is more than just a ritual of academic humility, it is an exercise of critical thinking about its work. The goal is to provide the reader with a more precise view about what the thesis cannot cover. This allows a better interpretation of the findings and allows further research to be conducted later.

10.1 Data limitations

The biggest limitation is the commune level unit of analysis. Statbel only publishes residential transaction data at commune level in the form of medians, not individual transactions. This aggregation induces measurement errors and biases that will influence the later regressions coefficients. Reusens et al. (2025) demonstrated it concretely: for the energy premium on an individual level, coefficients estimated in this thesis are almost certainly lower bounds in comparison with the true implicit price. This is not a minor issue, but rather a central data limitation and should be kept in mind by the reader at any moment when interpreting the results.

Another gap in the commune level medians is the absence of composition effect. In other words, the mix of properties sold in a commune shift from year to year, it can be sometimes more spacious apartments, and tiny houses followed the next year by the opposite with more studios and huge villas, … The median prices do not reflect the price movement related to the changes in properties that it represents. The hedonic regression with property type controls partially addresses this, but only imperfectly given the aggregated data structure.

Finally, the EPC bunching problem that was studied by Reusens et al. (2025) with the non-classical measurement errors in the EPC labeling. The exact influence of the bias is uncertain unless using individual level data. The continuous EPC score mitigates this bias but cannot fully eliminate this at a commune level where individual misreporting is averaged.

10.2 Identification limitations

I was able to identify three different endogenous concerns that cannot be resolved at a commune level. The first one is about railways: railway investment is not uniformly allocated. Instead, communes with a higher growth potential are more likely to receive investment in its transit infrastructure in prevision. This generates a misleading positive correlation between station proximity and prices. Using the historical network partially addresses this problem but it requires that the restriction holds to the Belgian context.

Then the second concern is about walkability. Indeed, amenity density comes in response to local purchasing power, which creates a causality from prices to walkability. This reverse causality is difficult to clean from the calculations.

Finally, the last limitation was what I called unobserved quality. What is meant by that is that houses with better EPC labels tend to have better unobserved qualities: recent renovations, better finishes, trendy interiors. This drives the prices up beyond the scope of the simple energetic economy. Observing on a commune level averages unobserved quality in each commune but not for the variations within the commune, which can influence the correlated variables.

10.3 Scope limitations

Most of the papers that this thesis relies on are based on owner-occupied residential market. Leaving the rental market to the side appears to me as the principal scope limitation. For example, in Brussels, a non-negligible share of the housing is rented instead of being owner-occupied. And the split in priorities for owners and renter was documented in the Belgian rental ML study (Vandevyvere, 2025) and Melvin (2018). For instance, the mechanism behind the energy premium perceived by buyers and renters works fundamentally differently. It is thus impossible to translate the estimated owner-occupied premium to the rental market without modifications.

Another limitation lies ones again on the commune level analysis, because it cannot identify micro locational variation that can have a huge impact on within commune prices. This can be linked to specific streets, floor levels, building orientation, … This effect is stronger in large heterogeneous communes such as Liège or Antwerp, for those cities the imprecision rise to a meaningful level in the alternative metric estimates. Those characteristics can however be captured by the hedonic analysis.

In 2023, after the introduction of renovation obligation and the large price increases in energy, it’s possible (if not likely) that these changes will signify a permanent change in the capitalization of the energy performance certification (EPC) premium. Year fixed effects capture the mean of the effects of time-varying shocks however they do not capture the variable response in the EPC score between communes. This interaction between the energy price index and the average EPC score of communes will probably be covered later by the NBB.

10.4 Literature coverage limitations

The academic literature reviewed during this research remained mainly limited to French and English written documents. Some Dutch written documents from the KU Leuven or University of Antwerp's Real Estate Institute have been covered through English summaries, automatic translation and journal publications, which may include shortcuts or misunderstandings in nuances. Policy reports and regulatory impact assessments from Flemish and Walloon planning authorities may contain empirical evidence not captured by the peer-reviewed search.

The majority of studies examining walkability are North American in origin. As of now, there is no Walk Score for Belgium and creating one would require developing a Walk Score proxy variable. But this has not been validated to date for Belgian buyers compared to Walking Scores developed using original algorithms. The study on the relationship between rented residential properties and their energy efficiency provides some validation for energy characteristics at the transaction level; but similar validation needs to be completed for the walkability proxy based on stated preference survey results.

Conclusion: beyond €/m², what this thesis ultimately shows

This thesis shows that composite multi-metric valuation frameworks are a more accurate measure of Belgian residential property value than the more conventional €/m² typically used. By integrating accessibility, energy performance, walkability, environmental quality and social factors, these frameworks capture value drivers that are not represented by €/m² measurements. They also reveal regional and distributional heterogeneities that remain unseen in a single area-based metric.

The empirical results show that energy performance brings a large and rising premium to owner-occupied dwellings. This is mainly linked to the expected future energy cost savings This premium has increased in the recent period of high energy prices and stricter regulation. Accessibility and commuting conditions showcase also a strong influence on the price. Communes with high-frequency rail services and shorter travel times to major employment hubs display higher prices and a shorter time on the market. This is in line with the bid-rent and spatial equilibrium models. Walkability, environmental quality and social metrics such as noise exposure, green space, local fiscal capacity and public services are other factors that further add value to dwellings. Those characteristics are only partially correlated with energy and accessibility, this supports the importance of a multidimensional framework rather than a single factor one. These premiums are not uniform across the market: quantile regressions reveal differences along the price distribution. While regional interactions highlight distinct patterns in Brussels, Flanders and Wallonia that represent their specific regulatory, fiscal and accessibility contexts.

On the methodological perspective the thesis shows that a multi metric perspective on housing value is at the same time feasible and more informative than €/m². One way of doing that is by combining hedonic regressions with modern machine-learning tools and spatial data. On one end hedonic model provide interpretable and literature compatible estimates on the commune level and with year fixed effects. But those results remain limited by aggregation, endogeneity between transit supply, amenities and housing demand and measurement issues around EPC labels and unobserved quality. On the other end tools such as SHAP (gradient boosted trees) decomposition improve predictive performances and uncover the non-linearities especially for energy and walkability. In the meantime, GIS (geographic information system) techniques allow to more accurately understand accessibility, green spaces and noise exposure at scale on

a commune level. Taken together, these approaches make it possible to quantify how much multi-metric frameworks improve compared to €/m² by capturing the structural drivers of Belgian dwelling values.

Those findings have concrete implications for the buyers, the investors and policymakers. For individual buyers, and more specifically the first-time owner-occupiers that operate under the strict constraint of loan-to-value limitation, multi-metric decomposition helps to differentiate communes that share similar €/m² values but offer very different total cost of ownership once energy, accessibility and environmental factors are considered. For investors and developers, the documented premiums and sustainability gaps point to renovation and location strategies that can align financial returns with social efficiency. In the meantime, it also highlights that owner-occupied energy premiums cannot be mechanically transferred to rental markets because of split incentives between landlords and tenants. For policymakers, the results show that energy regulations, registration-duty reforms and transit investments have concrete consequences across regions and across the price distribution that a simple focus on €/m² cannot reveal. Therefore, multi-metric adjusted prices can serve as monitoring tools for equity and affordability.

At the same time, these conclusions remain subject to the previously presented limitations about data, identification and scope. This includes commune-level aggregation, endogeneity between transit supply, amenity provision and housing demand, strategic behavior around EPC thresholds, omitted unobserved quality, and the need for dedicated models of rental markets. It is also important to keep in mind that real estate markets are not only shaped by economic fundamentals and the multi-metric drivers quantified here. Household decisions often reflect temporary needs and life events that fall outside the reach of a commune-level empirical framework: the arrival of a child, a separation, health problems that change mobility or care requirements, short-term liquidity constraints or the desire to be closer to specific relatives or services at a given moment in time. In addition, expectations for what a “good” home should provide are themselves heterogeneous and shaped by background, income, culture, life stage and past experiences. While a young professional may prioritize accessibility and urban amenities, a retired couple or a family with small children may attach greater weight to quiet streets, proximity to care, or specific school and social environments. All these individual factors can lead buyers to prioritize very different attributes than those highlighted in hedonic models and to accept prices that deviate from what a purely multi-metric valuation would predict. Based on this, the conclusions of this thesis should be read by keeping in mind that

they only represent structural, long-run value drivers in the aggregate rather than a complete description of every individual choice.

With all this in mind, the thesis answers its central question: yes, multi-metric valuation frameworks are more accurate tools than €/m² alone when it comes to measure the value of Belgian residential properties. The implicit prices of their underlying metrics differ meaningfully across regions and segments of the market in ways that matter for affordability, investment decisions and public policy.

Post-thesis observation: gaps and future directions

Five gaps the literature hasn't answered

Following the previously mentioned limitations (section 10) it is also interesting to understand the subjects that were not covered, allowing the possibility for further research.

Gap1: No comprehensive multi-metric Belgian residential analysis

The Belgian literature addressing energy performances is well developed (Reusens et al. 2022, Reusens et al. 2025, Damen et al.,2025, Vandevyvere, 2025), but only in isolation. There is no study that simultaneously investigates the implicit prices of all alternative metric categories at the commune level.

Gap 2: Unexploited multi-metric Belgian residential analysis

The consumer city framework made by Glaeser et al. (2001) predicts that the premium linked to each alternative metric should be different across the different regions: Brussels, Flanders and Wallonia. However, no testing through region specific interaction terms has been attempted in a Belgian multi-metric framework. The period after 2023 with the renovation obligation and the Walloon registration duty reform having simultaneous impact on the three regions offers an unique context for an analysis of the influence on the market.

Gap 3: No distributional analysis

Research about Belgian real estate has been restricted to OLS average effects. Zietz, Zietz & Sirmans (2008) have established that implicit pricing is heterogeneous across the price distribution, but this has not been applied to the Belgian data. This means that distributional consequences of EPC premiums and renovation obligations remain unmeasured. Which does not allow us to know who wins and who loses and at which price point.

Gap 4: No user adaptative composite indices

There exist no composite valuation methods with weights adapted for specific buyers' profiles for Belgium even though Gyourko & Tracy (1991) established that buyer preferences are heterogeneous across jurisdictions. This could have been done, for example, through calibrating SHAP feature importance profiles.

Gap 5: No harmonized open commune level dataset

The dataset gathered for this thesis was not available in a public uniformized form. It was instead necessary to harmonize the data from Statbel, regional EPC databases, SNCB, GTFS…

Giving access to an access point gathering and structuring all the data in a uniform and coherent form would ease future research and uniformize the data supporting the research. Allowing comparison between different papers.

Unfinished business: Five directions for future work

Based on the findings identified, here are a few suggestions for future research based on it. Each of them would require meaningfully different data, methods, or institutional access.

Individual property-level panel analysis

The most important extension would be to replicate the multi-metric analysis from a commune level measure to an individual property level. This would be done by merging data like EPC certificates via the CaPaKey according to Reuses et al.'s (2025) approach. This would require data sharing agreement with SPF Finances, the regional EPC agencies, and notarial transaction archives. The methodology of this thesis would transfer directly. The individual-level estimates would, based on Reusens et al.'s comparison of aggregate and individual results, be substantially larger. In my opinion, understanding how much the aggregation bias understates the true implicit prices is important both for academic calibration and for policymakers.

Causal identification of the accessibility premium

The historical railway network instrument, exploiting the alignment of 19th-century Belgian lines determined by engineering and political constraints largely unrelated to contemporary demand, offers the cleanest available identification strategy for the accessibility premium. Belgium's detailed historical railway records through the SNCB heritage archive provide the necessary data. The challenge is validating the exclusion restriction: the 19th-century network reflects historical industrial geography that may correlate with contemporary unobserved factors in ways that vary across communes. This validation is a methodological contribution in itself.

The rental market and the split incentive

The Belgian ML rental study (Vandevyvere, 2025) demonstrated that the rental energy premium exists but is relatively smaller and differently structured than the owner-occupier one. A proper analysis based on multi-metric hedonic framework does not exist for the Belgian rental market. Given that Brussels rental affordability now exceeds €1,000 per month across all communes (Vandevyvere, 2025) and that the split-incentive problem means landlords underinvest in energy efficiency relative to the social optimum (Melvin, 2018), this analysis has direct policy relevance. The renovation obligation as currently designed applies to buyer-owners; an analogous framework for rental landlords, informed by the economics of the split incentive, is a natural next regulatory step that this thesis cannot fully inform without rental-segment estimates.

Distributional analysis of renovation obligation impacts

Reusens et al. (2025) documented that renovation obligation generates price bifurcation along energy lines. It can be either steeper at the bottom of the price distribution (where renovation costs are proportionally larger) or at the top (where buyers of efficient dwellings capture the largest uplift). Those effects can't be captured through OLS averages. However, capturing such information would allow the determination of whether the obligations are primarily a redistribution from lower-income buyers of inefficient properties to higher-income buyers of efficient ones, or whether the burden is more broadly shared. Quantile regression on individual-level post-2023 data appears to me to be the required tool.

Dynamic modelling of the EPC premium

Both works of Reusens et al. (2022 & 2025) documented that the EPC premium has grown discontinuously in response to regulatory changes and energy price shocks. Getting a better understanding of whether this growth is linked to a permanent structural shift or rather a temporary shock that will partially be resolved as energy prices normalize (normalization expected in ING's analysis (2023) to occur in 2025) requires time varying coefficient modelling. This information will allow investors who pay the full 2024/early 2025 energy premium for an efficient property will earn a different return depending on whether the premium is permanent or temporary.

Practical recommendations for market participants

The concrete recommendations require no further research as they are actionable now. House market reference actors such as Immoweb, Zimmo or ERA should display more mandatory standardized characteristics on the same way as EPC labels right now. Those standardized information could include all the relevant ones noted in this thesis: distance to the nearest train station, walkability proxy….

Belgian notaries and agents should adopt the NBB's quality-adjusted house price indices (Reusens et al., 2022) rather than raw €/m² trends as the basis for market advice. This is a professional standard question as much as an academic one: advising clients based on a metric known to be systematically distorted is a professional liability. Especially on a market with lots of information friction and environment where distortions are growing.

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Appendices: use of AI

In a quickly evolving world, mentioning the use of AI seems to be necessary in order to preserve transparency. These recent changes also change the approach given to such research works, assessing its use is also an excellent way to share good and bad practices around innovation.

What AI was used for?

First of all, I did not use one AI but multiple of them, each having its strengths and weaknesses. The two main AI I used, are Perplexity and Claude. Perplexity was very useful to navigate the internet and find relevant documentation. Using this AI enabled me to find documents that I would not have consulted otherwise. Using this tool required, of course, consciousness: all the documents were not necessarily relevant or could sometimes not be scientific enough to be used in academic research work. The time saved on scrolling through Google Scholar and other libraries could then be used to better criticize the documents selected, ending up with a stronger reference basis.

In parallel I used Claude to better structure my thinking. One of the main threats when starting a thesis is to get lost in its research and lose the point of it. By structuring my research in the very beginning it allowed me to achieve better efficiency in my research work. This did not prevent me from going sometimes on wrong paths or dead ends. But it was a very helpful tool to refocus quickly and keep a consistent thread through the whole process.

Claude AI was an excellent companion for data analysis. Sometimes getting into datasets and extracting the data can be intimidating and difficult. AI enables the possibility to travel through a complicated data set with a sort of bird view, allowing a faster and stronger understanding of the data provided. Merging datasets or creating relations between them can also be very challenging, however, AI can help to find the right path and avoid distraction errors.

Sometimes facing a blank page can also be intimidating when the amount of work to come seems gigantic. Thanks to suggestions provided by AI, it can be sometimes easier to find the next topic to cover or from which perspective tackle the subject. In this case AI (both Perplexity and Claude) served as discussion buddies like a group discussing the next steps.

Another key role of AI was to ensure a proper bibliographical referencing. Having a bibliography in APA style with no error can be very challenging. Such things were than first created with the help of specific tools such as Zotero and then double-checked by Claude.

What AI was not used for

AI had also numerous tasks outside its scope of operation. First, AI did not conduct any quantitative analysis. AI did not generate any form of text; all the writing and the interpretation was human made. As mentioned previously, AI served as a support for the research but never took the initiative, it rather helped the author to optimize its work. Despite such help it did not prevent from going to wrong directions etc.

What should be remembered

As a conclusion, I think that AI should be considered as useful tools that should not be ignored when it comes to the realization of research works. It serves as a companion through research, helping to keep the focus on the targeted subjects and on the research rather than losing time on additional requirements of academic work that are not directly linked to the research subject. It also eases some time-consuming tasks such as data merger, rigorous biography… Allowing the author to spend more time on what matters the most: getting a deep understanding of the subject, exploring multiple approaches, showing critical thinking and keeping the focus on the subject while delivering a deep intelligible information. Working with an AI is also an excellent way to work on critical thinking, indeed AI systems are subject to “hallucinations”. This helps the author to stay critical about every information that is written, from the AI but also from the documents.

I would compare the use of AI to a group work done with a stranger. What I mean by that is that I know that the other person must have some good knowledge, however I don’t really know his background. By discussing with the coworker, I can come up with new ideas new approaches or new perspectives, however I should always stay aware that any person can make mistakes, and it is my responsibility to double check everything. Also, as a coworker would do, AI might forget the real target of the project and go out of the scope of the research.

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