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Real Estate valuation and forecasting

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Dedicated to Thekla[2], George[2] and Chrisanthi

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Abstract

Over the past decade, the Athenian residential real estate market has undergone profound structural transformations driven by a group of political, social, and macroeconomic developments, culminating in the COVID-19. The Greek real estate sector is characterized by informational inefficiency and spatial heterogeneity, primarily arising from a pronounced lack of market transparency; consequently, econometric modeling of this market remains a highly complex and fertile area of research. This study is grounded in and extends the quantitative framework established by Alexandridis et al. (2019). The study is focused in Athens, Agia Paraskevi, following the several parameters that have influenced the market, which increase the complexity of the models. Furthermore, Athens real estate market developments are of great interest to both local, national and international firms as well as to the public sector and government.

Initially, using existing literature we have investigated and discussed the several parameters influenced and still influence the changes in the market using data from GOLDEN DEAL S.M.S.A. Models were developed and compared linear and non-linear models based on regression and hedonic equations employing MATLAB functions and routines. Based on the model response sensitivity analysis was applied implementing both basic statistical tools and well-established mathematical tools to evaluate the importance of each parameter entering the models. Computational stability is achieved only through robust sample sizes and appropriate assumptions and deduplication.

The most powerful predictor of value across all model iterations was property area having a non-linear relationship with transaction price, which reveals a critical market phenomenon: the law of diminishing marginal returns and verifies the choice of the dependent variable instead of the normalized value per square meter. Other important parameters are the "Effective Age" over "Chronological Age», the floor level and the energy efficiency which has pushed mainstream demand toward renovating cheaper options. Variables such as local geography, Item_heating and Item_heating_medium are far from important parameters to influence transaction prices.

Keywords

Regression models, Real estate valuation, Hedonic valuation, Sensitivity analysis.

Περίληψη

Κατά την τελευταία δεκαετία, η αγορά ακινήτων στην Αθήνα έχει βιώσει αρκετές αλλαγές μετά από πολιτικά, κοινωνικά, οικονομικά γεγονότα, ακόμη και μια πανδημία. Η ελληνική αγορά ακινήτων είναι μια αναποτελεσματική και ανομοιογενής αγορά, η οποία διέπεται από έλλειψη πληροφοριών, επομένως η μοντελοποίησή της εξακολουθεί να αποτελεί ένα πολύ ενδιαφέρον και απαιτητικό πρόβλημα. Η παρούσα εργασία βασίζεται και έρχεται σε συνέχεια μιας υπάρχουσας εργασίας που δημοσιεύτηκε το 2019. Η μελέτη επικεντρώνεται στην Αθήνα, στην Αγία Παρασκευή, ακολουθώντας τις διάφορες παραμέτρους που έχουν επηρεάσει την αγορά, οι οποίες αυξάνουν την πολυπλοκότητα των μοντέλων. Αρχικά, χρησιμοποιώντας την υπάρχουσα βιβλιογραφία, διερευνήθηκαν και συζητήθηκαν οι διάφορες παράμετροι που επηρέασαν και εξακολουθούν να επηρεάζουν τις αλλαγές στην αγορά, χρησιμοποιώντας δεδομένα από το GOLDEN DEAL S.M.S.A.. Αναπτύχθηκαν και συγκρίθηκαν αποτελέσματα γραμμικών και μη γραμμικών μοντέλων που βασίζονται σε εξισώσεις παλινδρόμησης και ηδονικές εξισώσεις, χρησιμοποιώντας συναρτήσεις και ρουτίνες MATLAB. Με βάση την απόκριση του μοντέλου, εφαρμόσαμε ανάλυση ευαισθησίας, χρησιμοποιώντας τόσο βασικά στατιστικά εργαλεία όσο και καλώς ορισμένα μαθηματικά εργαλεία, για να αξιολογήσουμε τη σημασία κάθε παραμέτρου που εισέρχεται στα μοντέλα. Η υπολογιστική ευστάθεια επιτυγχάνεται μέσω κατάλληλων δειγμάτων, υποθέσεων και αφαίρεσης διπλότυπων δεδομένων.

Όπως προέκυψε από την ανάλυση, ο πιο ισχυρός προγνωστικός παράγοντας ήταν η επιφάνεια του ακινήτου που έχει μη γραμμική σχέση με την τιμή πώλησης, η οποία εμφανίζει ένα κρίσιμο φαινόμενο της αγοράς: τον νόμο της φθίνουσας αύξησης με την αύξηση της επιφάνειας και επαληθεύει την επιλογή της εξαρτημένης μεταβλητής αντί της κανονικοποιημένης τιμής ανά τετραγωνικό μέτρο. Άλλες σημαντικές παράμετροι είναι η «Πραγματική Ηλικία» έναντι της «Χρονολογικής Ηλικίας», ο όροφος και η ενεργειακή απόδοση, η οποία έχει ωθήσει την ζήτηση προς την ανακαίνιση φθηνότερων επιλογών. Μεταβλητές όπως η τοπική γεωγραφία, η θέρμανση και το μέσο θέρμανσης δεν αποτελούν σημαντικές παραμέτρους.

Λέξεις – Κλειδιά Ανάλυση Παλινδρόμησης, Εκτίμηση αξιών ακινήτων, Ηδονικά προσομοιώματα, Ανάλυση ευαισθησίας.

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List of Abbreviations & Acronyms

AI: Artificial Intelligence

ANNs: Artificial Neural Networks

ANOVA: Analysis of Variance

AVM / AVMs: Automated Valuation Model / Automated Valuation Models

AVP: Added Variable Plot

AWS: Amazon Web Services

CI: Confidence Interval

DCF: Discounted Cash Flow

ENFIA: Unified Property Tax (*Ενιαίος Φόρος Ιδιοκτησίας Ακινήτων*)

EPC: Energy Performance Certificate

EPR: Evolutionary Polynomial Regression

FDI: Foreign Direct Investment

FWL: Frisch-Waugh-Lovell (Theorem)

GBM: Gradient Boosting Machines

GDP: Gross Domestic Product

GFC: Global Financial Crisis

GIS: Geographic Information Systems

GSA: Global Sensitivity Analysis

hicp: Harmonized Index of Consumer Prices

HPM / HPMs: Hedonic Pricing Model / Hedonic Pricing Models

ICE: Individual Conditional Expectation

IVS: International Valuation Standards

KENAK: Greek Energy Performance Regulation for Buildings (*Κανονισμός Ενεργειακής Απόδοσης Κτιρίων*)

LAD : Least Absolute Deviation

LASSO : Least Absolute Shrinkage and Selection Operator

LTV : Loan-to-Value

MAPE : Mean Absolute Percentage Error

ML : Machine Learning

MRA : Multiple Regression Analysis

NBG : National Bank of Greece

NNs : Neural Networks

NPLs : Non-Performing Loans

NTUA : National Technical University of Athens

OAT : One-at-a-Time

OECD : Organization for Economic Co-operation and Development

OLS : Ordinary Least Squares

OMI : Real Estate Observatory (*Osservatorio del Mercato Immobiliare*)

PDP : PlotPartialDependence Plot

PwC : PricewaterhouseCoopers

Rcci : Real Construction Cost Index

RCOND : Reciprocal Condition Number

RF : Random Forests

Rgdp : Real Gross Domestic Product

RMSE : Root Mean Squared Error

RY : Refurbishment Years

SCA : Sales Comparison Approach

SMV : Similarity Measure Valuation

SSR : Explained Sum of Squares / Sum of Squares Residuals

1. Introduction

1.1. An Analysis of the Greek Real Estate Market: Valuation and Forecasting in the Post-Crisis Era

The Real Estate market in Greece experienced several phases of transformation during the last 25 years with the most important of them to be the period of financial crisis (Alexandridis et al., 2019). The latter reformed among other parameters or as a result of them, the property values and their important aspects. Moreover, following also the scientific development on estimating real estate values, methodologies of assessment and forecasting were also reformed. Given the above considerations, investors, policymakers and analysts must investigate the market's behavior during the past periods, especially considering the period of crisis. The progress from the low levels of the 2010–2018 period to the post-pandemic recovery 2012-2025 is the base to assess the current state of the market.

1.1.1. The Greek Real Estate Market During the Economic Crisis

The Greek crisis emerged as a result of the global financial crisis that began at the end of 2008, initiating a long period investorsof abnormal market conditions mainly defined by significant price declines. The main features of that period included (Alexandridis et al., 2019; Doumpos et al., 2020):

- **Price Contraction:** The market experienced a dramatic and sustained fall in property values. The steepest decline was observed until 2013Q1, whereas a smaller decline was observed until the end of 2014.
- **Market Inefficiency, Data Integrity, Analytical Challenges:** The Greek market was characterized by lack of information even before the crisis. Additionally, the financial crisis forced transactions in values less than representative prices. These facts did not enhance the efficiency of analytical model predictions and created a permanent noise in datasets, i.e. the lack of quantity and quantity of data disadvantaged analytical model estimation.

In order to perform accurate estimations of real estate values it is absolutely necessary to understand market conditions and factors, e.g. macroeconomic and property specific that drove market during the specific period.

1.1.2. Residential Real Estate Dynamics in Agia Paraskevi, Attica: 2008-2026

The current thesis focus on the area of Agia Paraskevi. In this paragraph we will discuss the path from 2008-2026.

1.1.2.1. The Collapse of Residential Value (2008–2017)

The main reasons of market collapse were the significant inefficiencies of the Greek economy. Unemployment was increased from 7.8% to 27.5% between 2008 and 2013, whereas family income reduced in average 33.3% between 2009 and 2017 (Kouretas & Vlamis, 2014). Moreover, credit market indices collapsed: while in 2008 more than 80% of estate deals were based on bank loans, by 2014, the bank lending was nulled due to non-performing loans (OECD, 2016). These facts led to an enormous supply while demand was zero: approximately 350,000 unsold properties were recorded in 2012 (NBG Macro Analysis, 2023).

Furthermore, additional pressure was placed on homeowners by additional regulatory measures, e.g. ENFIA. Given the increase in property taxes (PwC, 2015), many owners were forced to sell at lower-than-estimated prices in order just to fulfill their financial obligations (Kouretas & Vlamis, 2014).

1.1.2.2. The Turning Point and Initial Recovery (2018–2021)

The market reached its minimum in Q3 2017 when recovery began based also in foreign investments (Kapopoulos et al., 2020). The 2020–2021 pandemic period induced an unexpected increase provided that remote working conditions shifted demand toward new or renovated properties (BlackInvestor360, 2026).

Phase	Duration	National Price Trend	Key Drivers
Boom	2000–2008	High Appreciation	Excessive credit/mortgage lending

"Severe Declining"	2009–2017	-42.4% Cumulative	Austerity, ENFIA, Credit freeze
Revival	2018–2020	+1.8% to +7.4%	FDI, Golden Visa, Airbnb effect
Pandemic Pivot	2020–2021	+3.3% to +10.8%	Remote work, supply scarcity

Table 1: Evolution of real estate values 2000-2021

1.1.2.3. Post pandemic recovery (2021–2026)

The period 2021-2026 is characterized by recovery and stabilization in Agia Paraskevi (American-Hellenic Chamber of Commerce, 2025; Protothema, 2026; Global Property Guide, 2025; Akantziliotou & Papapetrou, 2025). Real GDP growth, which remained robust at approximately provided the necessary liquidity for a domestic and international buying spree; foreign Direct Investment (FDI) has been a primary catalyst for this growth (Akantziliotou & Papapetrou, 2025; Bank of Greece, 2025) which has ensured that demand consistently outstrips supply (Daly, 2024). This imbalance is a structural legacy of the 2010–2020 period, during which residential construction activity fell by nearly four times compared to pre-crisis levels (Global Property Guide, 2025; LSE Hellenic Observatory, 2024; Passportivity, 2025), which can be easily proved using the data analysis of the relevant Chapters of this thesis.

The Attica property market has performed as one of the strongest in Europe during this five-year window. Bank of Greece data reveals that apartment prices in Athens surged by approximately 9% in 2021, 13% in 2022, and 14% in 2023, before settling into a more sustainable growth rate of approximately 8.5% in 2024 and 6.6% by the third quarter of 2025 (Bank of Greece, 2025; Protothema, 2026).

1.1.2.4. Core Causes of Price Appreciation in Agia Paraskevi

The main driver is the imbalance between demand and availability. As can be also easily detected in our data in the following Chapters, construction activity distorted during crisis resulted in deficit of housing units. This is enhanced in Agia Paraskevi due to limited land availability (Passportivity, 2025; Grekodom, 2026; Global Property Guide, 2025). Furthermore, the construction cost has increased due to cost increase and labor shortages (Akantziliotou & Papapetrou, 2025) which were directly passed to the (Grekodom, 2026). Additionally, Golden Visa programs induced investment flows especially in areas close to transportation like some of Agia Paraskevi districts.

1.1.2.5. Micro-Geographical Valuation Dynamics in Agia Paraskevi

Agia Paraskevi is not a uniform market: it is divided in separate zones. The "College" area and "Stavros" are the most valued areas of the municipality (Indomio, 2025a) given that newer and premium dwellings are located in these areas. In contrast, areas like "Kontopefko," and “Paradeisos” remain the most affordable areas of the municipality because of the population density and older stock. However, given that Kontopefko and Paradeisos are close to major transport hubs, coupled with the affordability have made them a prime target for both local and international buyers (Global Property Guide, 2025).

Neighborhood Zone	Sale Price (€/m²)	Rental Price (€/m²/mo)	Change (2024-2025)	Market Profile
College	€4,229	€11.42	High Appreciation	Institutional/ Luxury
Stavros	€4,002	€11.11	Rapid Growth	Modern/Commuter
ERT	€3,530	€11.02	Stable	Established/Residential
Agios Ioannis	€3,440	€11.62	Moderate	Central/Commercial

Pefkakia	€3,396	€11.20	Moderate	Transit-Oriented
Tsakos	€3,386	€10.91	Stable	Scenic/Foothill
Paradeisos	€3,418	€11.49	High (+8.75%)	Balanced/Family
Nea Zoi	€3,201	€11.61	Moderate	Developing
Kontopefko	€3,185	€11.34	High Turnover	Value/Accessibility

Table 2: Spatial distribution of residential prices in Agia Paraskevi Evolution of real estate values 2004-2025

1.2. Thesis analysis

Based on the above analysis the thesis is organized as follows: Chapter 2 includes the literature review of the problem as already exists in previews works. Papers concerning the macro- and micro-parameters affecting real estate valuation are referred; time evolution and is also analyzed. Then existing works on the methodologies used to obtain real estate valuation are also discussed in the context and the position of the real estate properties. Then, Chapter 3 contains the research methodology which explains in details the parameters and the models used in the thesis. Data analysis and results using MATLAB© are included on Chapter 4. A complete set of sensitivity analysis and post-processing of the model results is included in Chapter 5. Chapter 6 contains some discussion and finally Chapter 7 summarizes findings, conclusions and recommendations for future works.

2. Literature Review

The collected sources focus extensively on the valuation of real estate properties, primarily residential, comparing traditional hedonic models (based on linear regression like OLS). Furthermore, the following paragraphs include discussion on the factors driving the market, on the models used for real estate valuation and finally the recent developments on the quantitative research.

2.1. The Macroeconomic and Structural factors

Real estate price changes are made due to the influence of several factors like **macroeconomic and financial factors** as well as **structural characteristics** of a property and its environment (Morano et al., 2022; Nikitidou et al., 2021; Bragoudakis, 2025). Some analysis can be found below

2.1.1. Macroeconomic and Financial Fundamentals (External Drivers)

2.1.1.1. A. Demand and Income Related Factors

- **Income and Wages:** Real house prices are fundamentally linked to income. The logarithm of the **annual average wage** is expected to exert a **positive effect** on house prices, capturing income elasticity. A decline in household disposable income dampens housing demand, thereby reducing prices. Similarly, **GDP** (Gross Domestic Product) is a determining factor for real estate demand and overall price fluctuations.
- **Employment and Unemployment:** The **unemployment rate** is a critical demand-side variable that negatively affects house prices. A drop in the unemployment rate boosts house demand and tends to lead to higher prices. High unemployment rates (such as those observed during the Greek crisis) reduce consumer purchasing power. In one study focusing on several countries, unemployment was found to have the greatest impact on residential real estate prices in Poland (Grum & Govekar, 2016).
- **Population and Demographics:** Growing **population** or demographic variables, such as household formation, increase the demand for housing. An increase in house demand resulting from **net migration** can lead to higher prices, particularly for smaller and older apartments in specific areas.

- **Expectations and Confidence:** Positive **expectations about the future course of the housing market** (e.g., concerning purchasing or constructing a home) boost current house demand and exert upward pressure on prices.

2.1.1.2. Monetary and Credit Factors

- **Interest Rates:** The **real interest rate** reflects the user cost of capital and is expected to exert a negative effect on housing demand and house prices. Lower interest rates reduce the cost of borrowing for a house, increasing demand and tending to lead to higher prices. The **central bank's base rate** directly influences the level of interest rates on loans, affecting the creditworthiness of buyers (Melnychenko et al., 2022).
- **Inflation:** Inflation is a key indicator of economic health (Melnychenko et al., 2022). It is considered the **main driver of housing prices** in cross-country studies. A positive link exists between rising inflation and real estate price changes. Real estate is often viewed as a good hedge against both expected and unexpected inflation (Melnychenko et al., 2022).
- **Credit Availability/Constraints: Access to credit** is a strong factor influencing price dynamics, generally showing a positive relationship. Conversely, **financing constraints**, proxied by the ratio of non-performing loans (NPLs) to total residential loans, lower housing demand and result in a drop in prices.

2.1.1.3. Supply and Regulatory Factors

- **Construction Costs and Supply: Real construction costs** (including construction materials and labor) are long-term fundamental determinants of house prices (Bragoudakis, 2025). The **phase of the business cycle in the construction sector** also determines supply dynamics. The **number of new built properties** influences the supply side, generally expected to exert a negative effect on prices by moderating demand-driven increases in the medium term.
- **Taxation and Regulation:** The **implicit tax rate on capital** (proxies the tax burden on holding property) is expected to negatively impact housing demand and prices (Alexandridis et al., 2019). Institutional factors, such as collateral and bankruptcy legislation and the fiscal treatment of owning versus renting, can shift demand.

2.1.2. Structural and Locational Factors (Micro Drivers)

Structural factors relate directly to the intrinsic nature of the property and its immediate extrinsic environment (Foryś, 2022; Numan & Yusoff, 2024).

2.1.2.1. Property Characteristics (Structural Attributes)

- **Size (Surface Area):** The **size of the property** is consistently identified as one of the **most important factors** for estimating house prices (Nikitidou et al., 2021). An increase in floor space is a significant factor in buying a house, offering convenience and more room. This positive correlation with total selling prices may diminish for very large properties (> 250 m²) due to a reduced buyer pool (Morano et al., 2022) while changes in the influence of size may vary as can be observed in the following Chapters.
- **Age and Condition:** The **age of the property** is a significant factor, typically having a **negative effect** on price, often attributed to higher maintenance costs, the need for renovation, and older construction techniques (Tarasov & Dessoulavy-Śliwiński, 2025). The **quality of the maintenance conditions** (e.g., 'to be restructured,' 'good,' or 'excellent') strongly affects market price, with improvement leading to increased value (Morano et al., 2022).
- **Floor Level:** The **level (floor)** of the property is a critical factor; a rise by one floor often **boosts value**, often due to better views and a more tranquil environment away from pollution and bottleneck traffic.
- **Amenities:** The existence of a **parking space** is an influential variable, particularly in overcrowded city centers, providing an advantage that increases property value. A dedicated **storage area** also plays a strong, positive role in house prices (Nikitidou et al., 2021).

2.1.2.2. Locational and Neighborhood Influences (Extrinsic Factors)

- **Spatial Effects and Location: Spatial effects** are a strong factor in real estate valuation (Doumpos et al., 2020) while real estate value is intrinsically tied to **fixed locations** and **geographic coordinates**. The municipal trade area in which properties are located is one of the most influencing factors on rental price dynamics. Location closer to the city center or tends to have the most substantial positive impact on the predicted price (Tarasov & Dessoulavy-Śliwiński, 2025).

- **Accessibility and Infrastructure:** Locational attributes include proximity to transportation and infrastructure. Increasing distance from locational variables such as the nearest **subway**, **central station**, **highway**, or **central pole** determines a reduction in total selling prices. Proximity to public transport infrastructure is a highly valued factor, demonstrating a 'premium' for increased service efficiency (Morano et al., 2022).
- **Environmental and Neighborhood Features:** These factors relate to the surrounding environment and facilities. Proximity to **urban green areas** (parks) is highly relevant and often corroborates a positive impact on selling prices. Neighborhood characteristics also encompass **socioeconomic conditions** such as the quality of schools (Nikitidou et al., 2021; Morano et al., 2022).

2.2. Automated Valuation Models (AVMs)

AVMs are well established systems incorporating statistical methods and possibly Artificial Intelligence (AI) and machine learning (ML) practices, to deliver in an automated manner, **effective and accurate estimates of property values** (Alexandridis et al., 2019; Deaconu et al., 2022; Doumpos et al., 2020). The most common model used from government bodies, and real estate professionals, is the hedonic price model, which describes a statistical regression where the dependent variable is the property price and independent variables are its characteristics, (Lancaster, 1966; Rosen, 1974; Pagourtzi et al., 2003). Hedonic models use historic data to forecast the price of properties in a fully interpretable manner providing also the corresponding uncertainties of the model results. Quality model results is improved and reevaluated by increasing data quality and history.

2.2.1. Financial and Risk Management Applications

Financial institutions, especially banks and mortgage underwriters, rely on AVMs for critical risk assessment and operational efficiency (Doumpos et al., 2020; Larraz, 2011; Numan & Yusoff, 2024; Alexandridis et al., 2019).

- **Risk Management:** AVMs provide essential tools for **risk management in real estate** for stakeholders like investors and financial institutions. They are crucial for **loan pricing and risk monitoring**.

- **Mortgage Collateral Assessment:** They are essential for **appraising collateral properties** that secure mortgage loans and for **mortgage quality control**, which involves the validation or verification of appraisals.
- **Portfolio Valuation and Monitoring:** AVMs provide an efficient means of **marking-to-market a large number of property values** for portfolio valuation. They monitor the level of **mortgage risk** that commercial banks are exposed to in terms of their Loan-to-Value (LTV) ratio.
- **Loss Mitigation:** In loss mitigation analysis, AVMs can be applied to estimate the current LTV ratio on non-performing loans to assist lenders in **determining optimal foreclosure strategies**.
- **Mitigating Economic Turbulence:** An efficient AVM can **mitigate the effects of price variations** caused by economic slowdowns, bubbles, or bankruptcy (Abidoye et al., 2019).

2.2.2. Government, Fiscal, and Policy Uses

AVMs assist public sector organizations, particularly central and local governments, in taxation and policy planning (Alexandridis et al., 2019; Morano et al., 2022):

- **Fair Property Taxation:** AVMs can help governments **set accurately the fair market value** of a property and determine accordingly **fair property taxes**. They derive proper objective real estate values that reflect **current market values**, making the process fairer while ensuring the government collects fair taxes.
- **Fiscal Planning and Market Transparency:** They assist central and local governments in **planning and implementing their fiscal policies** at both micro and macro levels. They promote cooperation toward public-private partnerships, implement property indices and performance measurements, and consequently make markets **more transparent and efficient** for investors and stakeholders.
- **Urban Planning and Public Housing:** AVMs are useful for **urban planning processes** and can support the **improvement of equitable public housing policies**.

2.2.3. Operational Support and Interpretative Tools for Appraisers

AVMs are intended to supplement, not replace, the appraiser's judgment, streamlining their workflow and supporting objective analysis (Alexandridis et al., 2019; Deaconu et al., 2022;

(Gružauskas et al., 2020) using data-driven estimates and interpreting effectively complex equations and dependencies. Some other advancements are described below.

- **Redesigning the Appraisal Process:** AVMs enable the **redesign of the appraisal process**. Their automation features **reduce the need for manual data collection and manipulation** by the appraiser, aiming to optimize valuation costs, quality, and time.
- **Appraisal Review and Verification:** They can be used as a tool for **appraisal review** and to **verify evaluations** by using a model developed by researchers. This eliminates some of the subjectivism valuators might experience when using a traditional market grid.

2.3. Evolution of Quantitative Research in Real Estate Valuation (2017–Present)

The main paper in AVM's research concerning the Greek market (Alexandridis et al., 2019) used historical prices of 35,000 properties concerning the crisis period (2012–2016). Three primary AVM methodologies were compared in this paper: a traditional hedonic model, a novel method based on spatial information and similarity metrics and Artificial Neural Networks (NNs). The main objective was to test the accuracy of the prediction of the models using data from the four quarters of 2016. In this study NN's are excluded due to lack of interpretability. Finally, notice also that AVM's research from 2017 also includes improvements in the sense of geographical and environmental variables (Alexandridis et al., 2019).

3. Research Methodology

3.1. Methodological Guide to Automated Real Estate Valuation

As already stated above, AVMs are objective and reliable models to estimate and predict real estate values (Morano et al, 2022) by processing large amount of data. Benefits and challenges of AVMs are presented below in Table 3.

Benefits of AVMs	Challenges of AVMs
Monitoring and Assessing Risk Management: (Doumpos et al., 2020).	**Resistance from the market:** Due to lack of familiarity they are considered threat instead of a useful tool (Foryś, 2022).
Fair and Efficient Taxation: Government uses AVM to perform systematic estimation to be used for taxation purposes (Alexandridis et al., 2019).	**Interpretability of NN:** ANN's inefficiency of interpretability makes difficult their use (Numan & Yusoff, 2024).
Improved Market Transparency: By standardizing the valuation process, AVMs make market operations more transparent and efficient for investors and stakeholders (Alexandridis et al., 2019).	**Risk of Critical Errors:** If not implemented correctly, AVMs can produce high levels of critical errors, undermining their credibility and utility (Rico-Juan & Taltavull de La Paz, 2021).
Reduced Manual Processes: Automation reduces the need for manual data collection and manipulation, freeing appraisers to focus on higher-value tasks (Alexandridis et al., 2019).	

Table 3: Benefits and Challenges of AVMs

This paragraph provides a methodological guide for implementing and interpreting (Armstrong, 2024) Hedonic Pricing Models. It will discuss data acquisition and cleaning, variable preparation and implementation of Hedonic models.

3.1.1. Data Acquisition

Data Acquisition is the first step of this work. Most of the success of the models depends on the quality, the quantity and the management of data:

- **Public/Semi-Public Databases:** Government bodies often keep valuable data (Morano et al, 2022; Larraz, 2011). Nevertheless, in our case Ministry of finance's database measures about 700 transactions for Agia Paraskevi since 2017 where also pricing cannot be evaluated and thus were not used.
- **Private Sector Data:** Many financial institutions possess databases which were not easy to access. Additionally, real estate advertisement companies and real estate agencies manage their own data (Doumpos et al., 2020). Our data were obtained from GOLDEN DEAL S.M.S.A.
- **Web-Based Sources:** Another source is Web where data acquisition can be performed using online platforms (Morano et al, 2022).

Quantity, quality and management of the data for this thesis will be discussed in the next Chapters.

3.1.2. Variable Preparation

A property's value is a function of its principal attributes. These variables form the independent variables of the model (Doumpos et al., 2020; Morano et al, 2022; Nikitidou et al., 2021):

- **Dependent Variable**
  - As already discussed the dependent variable is the total selling price **P**. Nevertheless, given that the value is large compared to the values of the attributes, model stability and interpretability is improved by using the natural logarithm of the Price **ln(P)**.
- **Structural Attributes**
  - Total Surface (S): The gross floor area of the property, typically in square meters.
  - Construction year: The year of property construction.
  - Floor Level: The floor on which the apartment or unit is located.

    - Room Counts: The number of bedrooms, bathrooms and other types of rooms in the property.
    - Condition (M): A qualitative assessment depending on construction year, possible renovations and maintenance.
    - Amenities: Several amenities like parking, Storage area, Basement, Elevator, Air Conditioning, pool etc.
- **Locational & Neighborhood Attributes**
    - Proximity Measures: The distance, often in kilometers, to key transportation hubs and infrastructure and points of interest.
    - Geographical Coordinates are also used from some complex models. Some less complicated models like the one discussed in this work incorporates the area districts as dummy variables.
- **Market & Economic Factors**
    - Local Market Indicators and Macroeconimic variables may also be included in complex models. Nevertheless, they are not taken into consideration in the current work.

3.1.3. Data Cleaning and Management

Raw data cannot be used directly for modeling. A systematic preprocessing is needed to attain data integrity and model stability (Doumpos et al., 2020; Morano et al, 2022; Larraz, 2011):

- **Data Cleaning:** Initially inaccuracies, inconsistencies, and outliers are located and removed. These choices are always dependent to the objectives of the model. In our work this is done continuously during the modeling procedure.
- **Variable Transformation:** In the same sense as using the price transformation, attributes may be transformed or normalized to reduce stability issues. In our case we didn’t choose to transform or normalize any other parameter except for the price.
- **Handling Categorical Data:** Qualitative attributes such as categorical or ordinal variables are handled accordingly to enter the model by converting them to numerical data.

3.1.4. Econometric and Hedonic Pricing Models (HPM)

The Hedonic Pricing Method (HPM) is a foundational econometric approach to property valuation (Doumpos et al., 2020; Foryś, 2022) a s already explained above. Furthermore, traditional hedonic models offer a clear framework for valuation but also come with significant limitations.

Strengths	Weaknesses
High Interpretability: The model describe in a very direct way how each attribute contributes to the price of the property (Foryś, 2022; Valier, 2020).	**Linearity Assumption:** HPM in their simplest form assumes a simple linear relationship between features and price. Nevertheless, log-transformations of variables and the inclusion of polynomial terms, may improve results and interpretation (Foryś, 2022). To address this issue we apply several non-linear terms in the regression
Foundation of Valuation: It is a well-established and foundational method in real estate economics (Sirmans et al., 2005).	**Spatial Limitations:** Standard HPMs struggle to account for spatial effects, where the impact of a feature can change depending on its location (Doumpos et al., 2020). In our model we use specific spatial area as a categorical variable.
Inferential Power: Excellent for understanding *why* prices are what they are, by identifying the statistical significance of different features (Valier, 2020).	**Vulnerability to Outliers:** OLS regression can be heavily influenced by unusual properties or transactions, potentially skewing the results (Schulz et al., 2019). Extended data analysis followed by the appropriate local and global sensitivity analysis provides improvements in this area.

Table 4: Strengths and Weakness of Hedonic models

While traditional hedonic models provide a clear and interpretable framework, their "one-size-fits-all" approach often fails to capture the critical role of geography. The next section explores models designed specifically to solve this problem.

3.2. Matlab® as a tool for Real Estate AVM models

This paragraph examines the technical affordances and drawbacks of implementing these models within MATLAB which is the tool to implement the solve the models discussed above. Notice that many of the points concerning MATLAB in this thesis are fully described in the Statistics and Machine Learning Toolbox™ which are described in https://www.mathworks.com/help/stats. MATLAB offers an integrated suite of toolboxes that facilitate the entire lifecycle of a valuation model, from geospatial feature engineering to parallelized deployment.

As already described above, the Hedonic Pricing Model (HPM) operates on the assumption that a property is a bundle of utility-generating attributes, and its market price is the sum of the implicit values of these attributes (Muhammad Nazrin et al., 2023). The fundamental equation is:

$$\ln(P) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n + \in$$

Where P is the dependent variable (sale price) and X_i represents characteristics such as area or floor level (Abidoye & Chan, 2018). The MATLAB environment solves these kind of equations using relevant functions adjusted to user preferences. MATLAB also enhances this procedures and estimation using diagnostic tools to detect multicollinearity and outliers as presented in the Table below

HPM Advantage	Description	MATLAB Support Mechanism
Interpretability	Direct estimation of implicit prices for each attribute.	fitlm Coefficient Table (Abidoye & Chan, 2018)
Simplicity	Computationally efficient for mass appraisal.	Regression Learner App

Regulatory Alignment	Meets standards for explainability in taxation and lending.	Automated Reporting
Diagnostics	Ability to test Gauss-Markov assumptions.	Residual Plotting

Table 5: Advantages of Hedonic Modeling in MATLAB

3.3. Sensitivity Analysis of Regression Methods in Real Estate Valuation

Sensitivity analysis is defined as a method to assess how and in what extend, changes in the input parameter values (independent variables) may influence the outcome of the model (dependent variable) to assess uncertainty and stability of the models (Frey & Patil, 2002; Saltelli et al., 2008; Thabane et al., 2013; Borgonovo et al 2016). Given our regression model which includes both categorical and numerical variables, sensitivity analysis serves also as an interpretative tool to real-world application. In the following we will provide some more details on this issue.

3.3.1. Theoretical points and necessity of sensitivity analysis in regression models

By performing sensitivity analysis several questions can be answered (Saltelli et al., 2008; Frey & Patil, 2002; Thabane et al., 2013). Sensitivity Analysis results can be used for variable selection, functional forms, and data cleaning procedures (Mowbray, 2021; Simonsohn et al., 2020), as also evidenced in the next chapters.

Professional sensitivity analysis is divided into local and global analysis (MJ Lindeman, 2025; Saltelli et al., 2008). In a model with five numeric and six categorical variables like the one discussed in the current work, local methods, such as calculating partial derivatives, only explore a tiny fraction of this space (Zhang et al., 2023). Then sensitivity output for Non-linear relationships may provide inconsistent results (Zhang et al., 2023; Saltelli et al., 2008).

In contrast, Global Sensitivity Analysis (GSA) measures the influence of variables over their entire domain, including non-linear relationships and interactions (MJ Lindeman, 2025;

Saltelli et al., 2008) by incorporating the probability distributions of the independent variables, (Sobol, 1993; Saltelli et al., 2008). The simultaneous application of this procedure to all identifies how the input variables collaborate to impact the dependent variable (Saltelli et al., 2008; Zhang et al., 2023). A comparison is presented in the following Table 6.

Feature	**Local Sensitivity Analysis (LSA)**	**Global Sensitivity Analysis (GSA/Sobol)**
Scope	Small perturbations around a nominal point (Zhang et al., 2023).	Full range of input parameter variation (Saltelli et al., 2008).
Interaction Detection	Generally unable to capture interactions (Saltelli et al., 2008).	Specifically quantifies higher-order interactions (Saltelli et al., 2008).
Non-Linearity	Often approximates non-linear models as linear (Zhang et al., 2023).	Robust to strong non-linearity and non-monotonicity (Sobol, 1993).
Computational Cost	Very low; requires few model runs (Zhang et al., 2023).	High; requires thousands of Monte Carlo samples (Sobol, 1993).

Output Interpretation	Sensitivity coefficients or partial derivatives (Zhang et al., 2023).	Fractional share of total output variance (Saltelli et al., 2008).
Primary Use Case	Model behavior near an expected value (Zhang et al., 2023).	Screening, ranking, and identifying interactions (Saltelli et al., 2008).

Table 6: Local vs Global Sensitivity analysis features

3.3.2. Sobol' indices used in sensitivity analysis of regression models

The integration of Sobol indices are a fundamental concept for sensitivity analysis application (Saltelli et al., 2008; Saltelli et al., 2010).

3.3.2.1. Mathematical Architecture of Sobol Sensitivity Indices

The Sobol method is attributed in the functional Analysis of Variance (ANOVA) decomposition (Saltelli et al., 2008; Sobol, 1993; Owen, 2013). For a model $Y = f(X_1, X_2, \ldots X_d)$, is expressed as:

$$f(X) = f_0 + \sum_{i=1}^{d} f_i(X_i) + \sum_{i<j}^{d} f_{ij}(X_{ij}) + f_{1,2\ldots,d}(X_1, \ldots., X_d)$$

In this structure, f_0 is the mean of the function, f_i captures the main effect of variable i, and f_{ij} represents the interaction between variables i and j (Sobol, 1993; Owen, 2013). Because these terms are orthogonal, their variances also sum to the total variance $V(Y)$ of the model output (Saltelli et al., 2008; Owen, 2013):

$$V(Y) = \sum_{i} V_i + \sum_{i<j} V_{ij} + \cdots + V_{1,2\ldots,d}$$

Each V_u term (where u is a subset of inputs) is the partial variance contributed by that specific set of inputs. Normalizing these partial variances by the total variance yields the Sobol indices (Saltelli et al., 2008; Sobol, 1993).

In professional practice, interpreting the 11-variable regression models as chosen in our case, requires calculating two distinct indices for each input to fully understand its role.

- **First-Order Index (S_i):** This index measures the contribution to the output variance of the main effect of variable X_i alone (Saltelli et al., 2008). It can be interpreted as the expected reduction in the output variance if X_i were to be fixed to a known value. This is translated in the following equation:

$$S_i = \frac{V_i}{V(Y)}$$

  This index is the most common measure used for variable ranking (Sobol, 1993; Owen, 2013).
- **Total-Effect Index (S_{Ti}):** This measures the total contribution of variable X_i to the output variance, including its individual effect and all of its interactions with other variables of any order (Saltelli et al., 2008). This is translated in the following equation:

$$S_{Ti} = \frac{E_{X\sim i}(V_{Xi}(Y|V_{X\sim i}))}{V(Y)}$$

  where $X_{\sim i}$ denotes all variables except X_i (Sobol, 1993; Owen, 2013), $E_{X\sim i}$ is the expectation (or average) taken over all possible values of all variables except X_i. This index is critical for "factor fixing" if a variable's total-effect index is near zero, it means that even its interactions are negligible, and the variable can be safely excluded from the model without loss of information (Saltelli et al., 2008).

3.3.3. Sensitivity analysis in MATLAB - Theoretical points

Sensitivity analysis in MATLAB can be performed by applying the specialized suite of diagnostic tools within the Statistics and Machine Learning Toolbox™ which are described in https://www.mathworks.com/help/stats. The analysis facilitates the identification of influential parameters, the simplification of complex architectures, and the assessment of robustness through both programmatic and graphical interfaces.

Four different methods are used in this thesis to assess sensitivity of the models:

- Analysis of Variance (ANOVA), is the primary mechanism to assess sensitivity
- Ranking of main effects through adjusted response functions using PlotEffects. This method provides the unique contribution of independent variables and uncover

hidden interactions, and establish a rigorous basis for model selection and optimization.

- Added Variable Analysis (partial regression leverage plots) based on the Frisch-Waugh-Lovell theorem, is used to assess the effect of adding a specific term to a multivariate model.
- PlotPartialDependence and Individual Conditional Expectation (ICE) plots, are used to assess non-linearities and interconnections. These methods allow for the visualization of the relationship between a predictor and the response while excluding the effects of all other predictors.

4. Data Analysis and Results

4.1. Data valuation, reliability and deduplication

4.1.1. Introduction

Data were provided from GOLDEN DEAL S.M.S.A. and include 11865 lines and 111 columns of advertisements in the corresponding site. Each line corresponds, typically, to a different advertisement and information for selling residences in the area of Agia Paraskevi, Attica. This area is located in North, North-East Attica area and consists of eleven districts/subareas: Kontopefko, Nea Zoi, Tsakos, Stavros, Aigiannis, Pefkakia, Profitis Ilias, Dimodidaskalon, Ipirou, ERT and Paradeisos (https://en.wikipedia.org/wiki/Agia_Paraskevi). The time period of the data starts from February 2021 and ends September of 2025. Each column corresponds to a different parameter of each property advertised (The proposed factors to be tested for their significant impact on transaction prices, based on statistical analysis, are highlighted):

- created_at Time created
- re_category Properties only
- rent_or_sell sell only
- priv_prof Privates or professional advertisements
- level1_geo, level2_geo, level3_geo, level4_geo, lng, lat, Item_property_zone
  Position of the residence
- Item_type Item_subtype
- Item_area
- Item_construction_year
- Transaction_price
- Item_level
- Item_refurbishment_year
- Item_bedrooms Item_master_bedrooms Item_bathrooms
  Item_wc Item_has_fireplace Item_has_parking
  Item_has_solar_boiler Item_has_aircon Item_has_garden
  Item_has_storage Item_semi_open_spaces Item_without_elevator
  Item_has_elevator Item_has_pool Item_has_secure_door

Item_has_tents Item_has_private_terrace Item_orientation
Item_view Item_garden_area Item_storage_area
Item_semi_open_spaces_area Item_terrace_area
Item_has_aluminium_frames Item_has_insect_screens
Item_has_playroom Item_pets_allowed Item_floor_type
Item_utilities_included_in_rent Item_alarm

- Item_energy_class
- Item_condition_specific
- Item_heating Item_heating_medium
- Item_is_suitable_for_investment
- Item_is_available_for_short_time_rent
- Item_has_night_time_electricity_discounts
- Item_antiparoxi_option
- Item_build_factor
- Item_build_license
- Item_buildable
- Item_buildable_area
- Item_building_area
- Item_can_drill Item_city_plan
- Item_cover_factor
- Item_dimensions
- Item_distance_to_shore
- Item_electric_door
- Item_electricity
- Item_elevator_payload
- Item_fenced
- Item_front_dimension
- Item_has_false_ceiling
- Item_has_false_floor
- Item_has_fire_detection
- Item_has_fire_extinguishing_system Item_has_goods_elevator
- Item_has_loading_ramp

- Item_has_loft Item_has_sewage
- Item_has_structured_cabling
- Item_has_vehicle_elevator
- Item_has_ventilation
- Item_has_wheelchair_accessibility
- Item_height
- Item_is_corner
- Item_is_equiped
- Item_is_furnished
- Item_is_see_through
- Item_loft_area
- Item_parking_area
- Item_parking_slots
- Item_sides
- Item_slots
- Item_tilt
- Item_total_area
- Item_usage
- Item_whole
- Item_with_no_communal_charge
- Item_is_suitable_for_holiday_residence
- Item_contains_building
- Item_parking_type
- Item_suitable_for_prof_use
- Item_suitable_for_students
- Item_agents_accepted
- Item_within_land
- Item_floors
- Transaction_is_negotiable
- Item_availability
- Item_land
- Item_style

- ad_id

4.1.2. Preparation/Validation of Data

4.1.2.1. Null values

It is evident that a number of the 111 factors listed above do not constitute significant determinants of real estate value in the context of residential use (e.g., apartments, houses, and buildings). Furthermore, the corresponding columns for some of the factors include null values. In particular, for each factor the null values for all 11865 lines are described below

level4_geo	Item_subtype	**Item_construction_year**	**Item_level**	**Item_refurbishment_year**	Item_bedrooms	Item_master_bedrooms	Item_bathrooms	Item_wc	**Item_area**
150	10179	**583**	**122**	**9837**	253	9846	486	5846	**1**

Item_orientation	Item_view	Item_garden_area	Item_storage_area	Item_semi_open_spaces_area	Item_terrace_area	**Item_energy_class**	**Item_condition_specific**
3393	9108	11392	10880	11834	11680	**608**	**2738**

Item_heating	**Item_heating_medium**	Item_property_zone	Item_floor_type	Item_utilities_included_in_rent	Item_electricity	Item_elevator_payload
2322	**4803**	9671	5911	11864	11343	11864

Table 7: Null values for each factor

The key factors of our analysis and their corresponding number of null values in the column are highlighted in bold in the tables above. Notice that some of the factors' null values, can be predicted based on some assumptions, i.e. since we have the longitude and latitude of the residence, if needed, data recovery can be obtained for the factor level4_geo.

4.1.2.2. Deduplication

It is very common in real estate advertising to encounter multiple listings for the same property. The reasons for the multiple advertisements are many:

- The main reason is that owners often give the same property to several brokers (non-exclusive mandate). In addition to brokers, the owner might post the property on classifieds and social platforms.
- Most of the times the same agent posts the listing on many portals (Spitogatos, XE, Facebook, Airbnb-style platforms for short lets, etc.)
- Outdated listings: Some ads stay online even after the price or availability has changed.
- Different pricing strategies: One agent may test a higher price, another a lower one.
- Even the longitude and latitude in advertisements may not correspond to the actual point of the property

Thus, validity of data with respect to duplication in listings, was performed in the following types: a. properties with the same longitude and latitude and b. properties with the same longitude, latitude, area and transaction price, c. properties with the same longitude, latitude, area and d. properties with the same longitude, latitude, and transaction price. Thus by removing duplicates properties of the (a) case were 3513 whereas for the (b) case were 9430, for the (c) 6854 and for the (d) 8819. Differences between (a) and (b) might include:

- Evolution of price
- Different information or misunderstanding or mistakes between owners and agents
- Market strategy of the owners and the agents
- Visual inspection of the data indicates that identical latitude and longitude coordinates do not always correspond to the same property

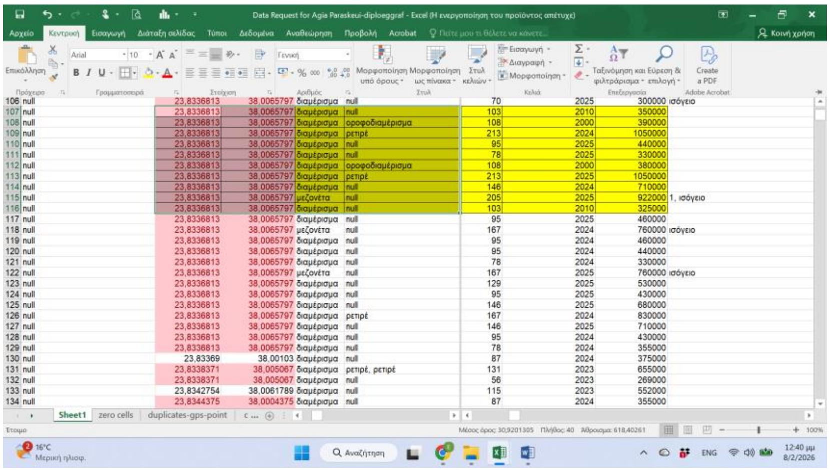

Figure 1: Data Inspection concerning latitude and longitude of the advertisements

Thus 5 different models will be used to evaluate results and the corresponding sensitivity analyses on the different effect of the quality of data in the value of the items.

4.1.3. Parameter definition

4.1.3.1. Time evolution

In a time dependent model, time may be introduced as a single independent variable. This assumption allows the inclusion of time evolution in price estimation (Anderson, 2016). In our case this time is included as the exact timing of advertisement uploads. Then each year is divided into four equal quarterly periods of three months each. Thus, time evolution is defined as a numerical variable ranging from 1 to 19, representing the sequential progression of these quarterly intervals across the study period.

4.1.3.2. Local spatial areas

The municipality of Agia Paraskevi is subdivided into 11 distinct geographical areas (ERT, Paradeisos, Nea Zoi, Stavros, Profitis Ilias, Agios Ioannis, Kontopefko, Pevkakia, Ipeirou, Tsakos, and Dimodidaskalon). Subsequently, location is treated as a categorical variable defined using 10 dummy variables where the reference category was selected as the area exhibiting the highest property values. Null values of the data were synthesized using longitude and latitude.

4.1.3.3. Item area

The normalization of the dependent variable by the corresponding floor area was considered, and alternative models were tested using property area as an independent numerical variable. Model validation procedures proved that considering floor area as independent variable was more efficient than assuming the dependent variable normalized by the floor area and produced more efficient and reliable outcomes. Consequently, the absolute property value was retained as the dependent variable, while the floor area of each property was incorporated as a separate numerical independent variable in the final regression models. Null value was deleted.

4.1.3.4. Constructed year - Extreme values

Values of constructed items before 1940 was removed (9 lines) for the current numerical variable. Additionally, items having null values in the construction year were also removed (583 lines) and numbering of the construction year started from 0 for the year 1940. Null values were deleted.

4.1.3.5. Refurbishment vs Condition

The year of refurbishment is connected to the year of construction. Furthermore, refurbishment year can be connected to the condition of the item. Given the previous observations, these two parameters can be merged to the condition of the item. Missing data from the condition can be retrieved from refurbishment years (RY) by assuming that:

- If RY > 2016 the condition is considered refurbished
- If RY < 2016 and RY> 1996 the condition is considered good
- If RY < 1996 and RY> 1996 the condition is considered needs refurbishment

Notice also that null values in both areas are removed from the table. Moreover, the property condition is treated as a categorical variable consisting of six distinct categories: good condition (καλή κατάσταση), under construction (υπό κατασκευή), newly built (νεόδμητο), renovated (ανακαινισμένο), semi-finished (ημιτελές), and requiring renovation (χρήζει ανακαίνισης). Consequently, five additional dummy variables are introduced into the regression model, with one category serving as the reference group to avoid multicollinearity and ensure proper parameter estimation. The reference category was selected based on its highest frequency in the dataset, namely the semi-finished (ημιτελές) category.

4.1.3.6. Item heating

Heating type is treated as a categorical variable consisting of four distinct categories: autonomous heating with central installation (αυτόνομη θέρμανση με κεντρική εγκατάσταση), autonomous heating with individual installation (αυτόνομη θέρμανση με ατομική εγκατάσταση), central heating (κεντρική θέρμανση), and no heating (χωρίς θέρμανση). Accordingly, three additional dummy variables are introduced into the regression model, with one category serving as the reference group to avoid multicollinearity and ensure proper parameter estimation. The reference category was selected based on its highest frequency in the dataset, namely the autonomous heating with individual installation (αυτόνομη θέρμανση με ατομική εγκατάσταση) category. Null values were deleted.

4.1.3.7. Item heating medium

Energy source is treated as a categorical variable consisting of four distinct categories, as well as their possible combinations: oil (Πετρέλαιο), natural gas (φυσικό αέριο), electricity (ρεύμα), and pellet. Accordingly, three additional dummy variables are introduced into the regression model, with one category serving as the reference group to avoid multicollinearity and ensure proper parameter estimation. The reference category was selected based on its highest frequency in the dataset, namely natural gas (φυσικό αέριο). Null values were deleted.

4.1.3.8. Energy class

In contrast to the above choices, Energy class is considered as an ordinal variable with 10 subcases (A+, A, B+, B, Γ, Δ, E, Z, H, NULL. Null values in this category were removed from the dataset.

4.1.4. Model Definition and validation

Based on the preceding methodological considerations, the initial regression models were classified into five categories, labeled A–E, according to the real estate deduplication procedure applied to the dataset. The classification criteria were defined as follows:

- **Model A**: Properties with identical longitude and latitude coordinates
- **Model B**: Properties with the same longitude, latitude, floor area, and transaction price
- **Model C**: Properties with identical longitude, latitude, and floor area
- **Model D**: Properties with identical longitude, latitude, and transaction price
- **Model E**: Full dataset without the above restrictive deduplication criteria

Following the above mentioned data cleaning and processing, the resulting sample sizes were as follows: Model A contained 3,513 observations, Model B 7,364 observations, Model C 5,353 observations, Model D 6,900 observations, and Model E 8,862 observations.

Then, different kind of models were also considered in order to validate data and model robustness, and enhance predictive performance:

- **Model 1**: Includes only the lines having non-null values in all variables. For example, Model 1E contains 4,779 observations.
- **Model 2**: Represents the baseline dataset following the previously described preprocessing and deduplication procedures, without additional imputation of missing values. Model 2E contains 8,862 observations.
- **Model 3**: Includes observations where some missing values were estimated or completed using relevant auxiliary information and methodological assumptions. This model incorporates the assumptions described in Section 1.1.5 and provides the largest dataset, with Model 3E containing 10,986 observations.

Therefore, each final model is identified using a two-level notation: the first index (1–3) indicates the data treatment strategy, while the second index (A–E) denotes the deduplication category. The complete structure of the models is presented in the following Table.

	Model 1*	Model 2*	Model 3*
Model *A	2111	2866	3343
Model *B	4304	7364	8791
Model *C	3058	5353	6384
Model *D	4086	6900	8223
Model *E	4779	8862	10986

Table 8: Number of data for each Model

4.1.5. Assumptions for Models *3

4.1.5.1. Natural Gas initiation

The organized supply of natural gas in Attica began during the late 1990s and early 2000s with the establishment of EPA/EDA Attica. Initial network penetration primarily occurred in central and densely populated urban areas, while expansion to suburban municipalities was gradual. In the northern suburbs of Athens, including Holargos, Agia Paraskevi, and Chalandri, substantial network expansion occurred approximately between 2005 and 2010, while widespread availability and market maturity were largely achieved after 2010. The adoption of natural gas in residential buildings closely followed the development of the distribution network:

- **Before 2005:** Nearly all newly constructed apartment buildings primarily used oil-based heating systems.
- **2005–2010:** New residential developments gradually began incorporating infrastructure provisions for natural gas, particularly in areas where network access existed.
- **After 2010–2015:** Natural gas became an almost standard heating option, accompanied by a significant increase in autonomous per-apartment heating installations.

At present, natural gas is available across a large part of Attica and continues to expand. Newer residential buildings, particularly those constructed after 2015, are systematically designed with either: individual natural gas boilers, or alternative energy-efficient systems such as heat pumps, mainly due to stricter energy regulations.

4.1.5.2. Energy class estimation with respect to the construction year

The implementation of the Greek Energy Performance Regulation for Buildings (KENAK) in 2010 fundamentally transformed construction standards and energy efficiency requirements for residential properties. Based on construction year, an indicative energy classification was assigned as follows:

- For the buildings constructed before 1980 was assumed a typical energy category of H due to non-mandatory insulation requirements)
- For the buildings constructed in the period 1980–2010 (Thermal Insulation Regulation Period), was assumed a typical energy category of **E**

- For the buildings constructed in the period 2010–2017 (Initial KENAK Implementation) was assumed a typical energy category of **C.**
- For the buildings constructed in the period 2018 Onwards (Revised KENAK). was assumed a typical energy category of **B**

4.2. MATLAB® Implementation of the Regression models

4.2.1. MATLAB® routine selection

4.2.1.1. Hedonic models

The MATLAB® Statistics and Machine Learning Toolbox includes several functions for regression, each corresponding to the user needs (Table 9).

Function	**Primary Application**	**Input Data Format**	**Key Characteristics**
fitlm	Multiple Linear Regression	Table or Matrix	Modern, object-oriented, supports Wilkinson notation and extensive diagnostics.
mvregress	Multivariate Linear Regression	Matrix or Cell Array	Handles multiple correlated responses; essential for longitudinal and panel data.
regress	Multiple Linear Regression	Matrix	Legacy function; useful for simple scripts and loops but lacks advanced object features.

stepwiselm	**Automated Model Selection**	**Table or Matrix**	**Iteratively adds/removes terms based on p-values or information criteria.**
fitglm	Generalized Linear Models	Table or Matrix	Supports non-normal distributions (e.g., Poisson, Binomial) via link functions.
plsregress	Dimension Reduction	Matrix	Partial Least Squares; ideal for high-dimensional data with multicollinearity.

Table 9: Matlab routine's comparison for implementing hedonic models

For the purposes of a master thesis the choice of an automated procedure was considered appropriate, i.e. stepwiselm was chosen for the implementation. This algorithm iteratively adds or removes predictors based on the p-value of their F-statistics, ensuring that only those variables with a statistically significant contribution to the reduction of the residual sum of squares are retained.

4.2.2. Implementation of the hedonic model - stepwiselm routine

The corresponding function is described in MATLAB® Documentation (https://www.mathworks.com/help/stats/stepwiselm.html) and the stepwise regression in (https://www.mathworks.com/help/stats/stepwise-regression.html). The procedure has several points to be discussed and defined to achieve a credible and optimum solution. One important point in this vein the choice of the model/equation to be used for the approximation and the quality/quantity of its terms. The options of the routine are described in the Table below

Value	Model Description
"constant"	Model contains only a constant (intercept) term
"linear"	Model contains an intercept and linear term for each predictor
"interactions"	Model contains an intercept, linear term for each predictor, and all products of pairs of distinct predictors (no squared terms)
"purequadratic"	Model contains an intercept term and linear and squared terms for each predictor
"quadratic"	Model contains an intercept term, linear and squared terms for each predictor, and all products of pairs of distinct predictors
"poly*ijk*"	Model is a polynomial with all terms up to degree *i* in the first predictor, degree *j* in the second predictor, and so on. Specify the maximum degree for each predictor by using numerals 0 through 9. The model contains interaction terms, but the degree of each interaction term does not exceed the maximum value of the specified degrees. For example, "poly13" has an intercept and x_1, x_2, x_2^2, x_2^3, x_1*x_2, and $x_1*x_2^2$ terms, where x_1 and x_2 are the first and second predictors, respectively.

Table 10: Options for stepwiselm

The initial model used was the linear, which was improved using purequadratic option. Interaction terms for all the cases cannot be considered given that the amount of data is small based on the warnings of MATLAB®. For model 1C, even quadratic terms cannot be added given the small amount of data. Then given our knowedge on data and market, model results were improved by adding first order interactions of Item_construction_year with Item_condition_specific.

Finally, it should be noted that a categorical variable is retained in the regression model if at least one of its associated dummy variables exhibits a p-value below 0.05, thereby satisfying the criterion for statistical significance. Under this condition, the categorical variable is considered to exert a statistically significant effect on the dependent variable and is consequently included in the final model specification.

4.2.3. Hedonic model results

Given the function stepwiselm, several draft runs were made and some of them their results appear in the attached docs, which are named after the model data, the type, the upper model used (linear or quadratic, without interaction terms) and the mape computation. The runs include model 1, 2, 3 of type C, B, D and E. The final results having the interaction discussed above for the most credible models (2A, 2B, 2C, 2D, 2E), are also included in Appendix A. Results include the regression output along with the relevant MAPE value. It can be observed that in terms of R^2 (=0.839) and MAPE (=13.92) the optimum choice is the 2D model whereas the 2B-2E models do not fall far from these values R^2 (=0.837-0.830) and MAPE (=14-15) and 2A falls short more, i.e. R^2 (=0.800) and MAPE (=15.56). Furthermore, using the same approach models 1B, 1D, 1E and 3B, 3D, 3E are presented in Appendix A for reasons of validity.

4.2.3.1. Differences of model results concerning cases 1*, 2*, 3* - Computational instability

Given the output of the models 1B, 1D, 1E and 3B, 3D, 3E, we can easily observe warnings concerning computational stability. To understand the warnings produced by MATLAB®'s Statistics and Machine Learning Toolbox, it is necessary to examine the underlying linear algebra of the Ordinary Least Squares (OLS) estimator. In a standard linear regression model, the objective is to solve for a vector of coefficients that minimizes the sum of squared residuals. If some columns of the matrix to be inverted are perfectly linearly dependent - a condition known as perfect multicollinearity - the inverse matrix is singular and lacks an inverse. In practical real estate applications, perfect singularity is rare, but "near-singularity" or "ill-conditioning" is frequent.

MATLAB® utilizes the as a scale-invariant diagnostic to assess how close a matrix is to being singular. The RCOND value ranges from 1.0, representing a perfectly well-conditioned matrix, to 0, representing a singular matrix. When RCOND falls below a certain threshold - typically near the machine epsilon for double-precision arithmetic (~$2.22*10^{-16}$) - MATLAB® issues the warning that "Results may be inaccurate". In the provided diagnostic logs, models such as Model 1D and Model 3D report RCOND values in the magnitude of 10^{-17} and 10^{-18}, which are dangerously close to the limit of computational reliability. Notice that for model 2D, RCOND= $5.12*10^{-09}$. Analysis of the data indicates that the Model 1 group, which possesses the lowest observation counts (4,000-4,700 range) while maintaining high term counts (12-14), exhibits the most severe instability, with RCOND values dipping into the 10^{-17} magnitude. In contrast, the Model 2 group appears both computationally stable, without diagnostic messages and statistically efficient having high R-squared values (approximately 0.83-0.84) and MAPE. This suggests that Model 2 is more efficient than Model 1 and 3.

Deepening in the results we can mention that ill-conditioning in real estate models typically results from multicollinearity, scaling disparities and sparsity of observations (Belsley, 1991):

- Multicollinearity can be observed, e.g. between a property's total area and its number of rooms, when the variables can be correlated, or when categorical dummy variables define nearly identical sets of observations.
- Scaling disparities occur when the magnitude of numerical values varies in a great extent, such as having construction years (e.g., 2020) alongside binary indicators (0 or 1) and squared area terms (e.g., 250,000). In our case efforts were given to reduce scaling disparities by using construction years' values starting from 0 to 75 from 1950 to 2026 and removing outliers of more than 800 sqm for the area. Nevertheless, computational efficiency remained low for Models 1 and 3.
- Finally, the fragility of the design matrix can be indexed from the fact that in some cases even if predictors and equation are defined, determining p-values and F-statistics-fails numerically. The main reason of this is the sparsity of observations at specific variables and categories (Kutner et al., 2005), which increase to numerical instability.

A summary of the computational stability results and efficiency of the optimal models, Model 2 group, is presented in Table 11. Additionally, the low MAPE values (minimum in ~14%) indicate that these stable models are highly effective at predicting transaction prices.

Model Identifier	Observations (N)	R-Squared (R^2)	Adjusted R^2	RMSE	MAPE (%)
Model 2A	2,865	0.802	0.799	0.218	15.5594
Model 2B	7,363	0.837	0.836	0.202	14.2269
Model 2C	5,354	0.834	0.832	0.211	14.9509
Model 2D	6,900	0.839	0.838	0.201	13.9208
Model 2E	8,860	0.833	0.832	0.203	14.3828

Table 11: Model 2 group results and stability output

The stability of Model group 2 is ensured due to the robust sample sizes (ranging from 6,900 to 8,860 observations) with respect to the number of predictors (12 terms in 8 predictors). In contrast, Model group 1 and 3 iterations frequently trigger singularity warnings as summarized below (Table 12).

Model	Key Features	R-Squared	RCOND	Stability Issue
Model 1D	13 terms, 9 predictors (incl. time)	0.804	$2.44*10^{-17}$	Singular during ANOVA [1]

Model 1B	12 terms, 8 predictors	N/A	$2.50*10^{-17}$	Singular Matrix [1]
Model 3D	11 terms, 7 predictors (incl. area^2)	0.738	$1.08*10^{-16}$	Badly Scaled [1]
Model 3B	11 terms, 7 predictors (incl. year^2)	0.736	$1.10*10^{-16}$	Badly Scaled

Table 12: Model 1 and 3 group results and stability issues

4.2.4. Model results for 2* models

As already mentioned, Model group 2 exhibit remarkably consistent performance metrics and a level of accuracy that is considered highly effective for real estate markets (Abidoye & Chan, 2018).

4.2.4.1. Exclusion of advertisement/transaction time in the regression models

The exclusion of the assumed transaction time variable (represented by the 1-19 quarterly scale from Q1 2021 to Q3 2025) suggests that the specific time periods are not important factors compared to physical and structural attributes of a real estate property. While absolute prices may have trended upward, the *relative* importance of the property's physical characteristics (size, floor, and condition) remained the dominant drivers, making the exact timing of the advertisement secondary. Finally, we should also mention that in many hedonic models, temporal trends are often highly correlated with structural improvements or changes in energy standards that occur over the same period. If the price increases were already well-explained by the "New-Build Premium" or the "Green Shift" captured by `Item_construction_year` and `Item_energy_class`, the time variable would be flagged as redundant and removed by the stepwise algorithm (Herath & Maier, 2010). Furthermore, if price appreciation was highly correlated with newer construction entering the market, the stepwise routine would exclude the time variable as redundant.

Additionally, it should be highly noticed that real estate market often renews advertisements of the same property by slightly changing area, value or geographical position of the residence in order to obtain a better position in the market. This type of market intervention may enhance the exclusion of advertisement time from the regression model.

4.2.4.2. The effect of the Item_Area

The most powerful predictor across all models is the property area, which explains the vast majority of the variance in transaction prices. However, the relationship is not purely linear. The models incorporate a quadratic term (Item_area^2) which reveals a critical market phenomenon: the law of diminishing marginal returns (S. Frey, 2026), (Table 13). The values and the signs of the terms indicate that while total price increases with area, the rate of increase decreases as the area becomes larger and the non-linear term becomes more important. This observation reflects the market: while area grows, the incremental value of extra space often decreases.

Model Component	**Coefficient (Estimate)**	**t-Statistic**	**p-Value**
Item_area	0.010036	97.505	0
Item_area^2	-1.0351e-05	-49.183	0

Table 13: Regression results for the parameter Item_area

This means, e.g. that a studio may command a premium price per unit area, whereas a large villa faces higher maintenance costs and a more limited buyer pool which decreases value per square meter.

4.2.4.3. The effect of the Construction year

Again, similar to the area of the property, the relationship between the year of construction and property value is also non-linear. Nevertheless, since both the linear and non-linear terms are positive, as year approaches the last decade values are increasing non-linearly.

This approach reflects the shift toward environmental and safe – in the sense of seismic standards - properties that characterize the Attica market in the contemporary era. Considering also that - as can be easily observed in the following - construction was nullified during crisis, which created a supply gap, a newly built (νεόδμητο) apartment in 2026 defines a significant premium over older properties.

4.2.4.4. The effect of the Floor level

In the Athenian real estate market is already known that floor level is a significant driver and this also observed in the results for various levels as can be observed in the following table given the coefficient of the terms (Table 14)

Floor Level	**Coefficient (Estimate)**	**Relative t-Statistic**	**p-Value**
Semi-Basement (ΗΜΥΠ)	0.15957	3.05	0.00224
Ground Floor (ΙΣ)	0.68168	14.76	1.28e-48
1st Floor (1O)	0.75225	16.41	1.81e-59
2nd Floor (2O)	0.77917	16.94	3.62e-63
3rd Floor (3O)	0.84723	18.39	6.26e-74
4th Floor (4O)	0.90155	19.57	3.25e-83
5th Floor (5O)	0.91737	19.69	3.73e-84

6th Floor (6O)	0.95621	19.91	5.56e-86
7th Floor (7O)	1.01810	6.79	1.20e-11
8th Floor (8O)	0.93424	15.26	8.72e-52

Table 14: Regression results for the parameter Floor level

The above results can be related to natural lighting, reduced street-level noise, and unobstructed views.

4.2.4.5. The effect of Energy Class

The models point out "green premium" for efficient buildings: Coefficients for energy classes relative to an A+ baseline decrease with lower ratings as expected in the market. (Model 2D, Table 15):

Energy Rating	**Coefficient (Estimate)**	**p-Value**
Class A	-0.0327	0.00094
Class B	-0.0715	1.09e-05
Class Γ	-0.1113	2.54e-12
Class Δ	-0.1130	1.05e-12
Class E	-0.1577	1.84e-22

Class Z	-0.1460	6.43e-15
Class H	-0.1534	2.58e-23

Table 15: Regression results for the parameter Energy Class

The difference between the premium class and the lower class derives a decrease of roughly 15%, defining energy efficiency, in the recent models as a mandatory valuation factor.

4.2.4.6. The neighborhood effect

Agia Paraskevi possesses distinct residential zones with varying prices. In Model 2E, neighborhood coefficients allow for a quantitative ranking relative to a high-prestige baseline district. Similar results appear for Model 2D where again the greater difference with respect to the base value which corresponds to the district Κολλέγιο, measures ~13% (Appendix A) whereas the other values are lower than 0.06.

Neighborhood (level4_geo)	Estimate (Price Adjustment)	t-Statistic	p-Value
Stavros	-0.00577	-0.70	0.4791
Νέα Ζωή	-0.02237	-2.25	0.0243
Προφήτης Ηλίας	-0.03673	-3.92	8.90e-05
Τσακός	-0.04037	-3.36	0.00075
Παράδεισος	-0.04502	-5.36	8.51e-08

Κοντόπευκο	-0.05798	-7.93	2.37e-15
Πευκάκια	-0.14333	-12.69	1.34e-36

Table 16: Regression results for the neighborhood effect – Model 2E

4.2.4.7. Interaction effects

A significant driver of the 2D Model results is the presence of interaction terms between Item_construction_year and Item_condition_specific, i.e. the chronological age of a building is often less important than its "effective age," which accounts for maintenance and renovations (Shultz, 2018; Cotality, 2016). The negative sign of the interaction terms (e.g., Year: ανακαινισμένο) generally show negative coefficients (e.g., -0.01339 in Model 2D), reduce overestimation of the renovated properties with respect to the newer properties. In the same time, for older properties, the positive main effect of being "renovated" shifts the “age” of the property towards the renovation age.

In summary, the models produce a highly reliable (MAPE ~14%) framework that reflects a rational, structural-driven market where physical attributes and modern standards of efficiency take precedence over speculative timing.

5. Model Sensitivity Analysis

As already stated in Chapter 3, sensitivity analysis is applied using both a. simplified and b. well-defined mathematical methods. In particular, as far as simplified method are concerned, a first attempt concerning sensitivity analysis is obtained using ANOVA analysis. Then PlotEffects, PlotAdded and PlotPartialDependence plots are also used to discuss sensitivity. Well defined mathematical methods are finally analyzed using Sobol' indices both in local and global analyses.

5.1. ANOVA analysis

Model 2D (N=6,900) provides the most statistically efficient representation of the current market, achieving the lowest MAPE (13.92%) and the highest adjusted R^2 (0.838) among the analyzed sets. By deconstructing its ANOVA table, we can identify the specific hierarchical sensitivity of property value to its constituent features. The sensitivity of a model to a particular variable is measured by its **Explained Sum of Squares** (SSR). In Model 2D, the total variation in transaction prices ($SSR = 1113.78$) is partitioned as follows :

Source of Variation	**Sum of Squares (SumSq)**	**% of Explained Variation (SSR)**	**F-Statistic**	**Significance (p-Value)**
Item_area (Linear + Quad)	719.86	85.98%	15,410 / 2,419	0
Item_level (Floor)	65.20	7.79%	134.58	$1.36*10^{-303}$
Item_condition_specific	15.71	1.88%	77.80	$1.31*10^{-79}$

Construction Year (Linear + Quad)	11.97	1.43%	141.0 / 155.4	$3.25 * 10^{-32}$ / $2.70 * 10^{-35}$
Year:Condition Interaction	8.39	1.00%	41.55	$2.81 * 10^{-42}$
Item_energy_class	5.44	0.65%	16.84	$5.40 * 10^{-25}$
level4_geo (Spatial)	5.29	0.63%	13.11	$4.81 * 10^{-25}$
Item_heating (System + Medium)	5.39	0.64%	39.5 / 5.0	$2.69 * 10^{-25}$ / 0.0017
Total Explained (SSR)	**837.25**	**100.00%**	0.00	0.00
Error (Residuals)	**276.53**	0.00	0.00	0.00

Table 17: ANOVA analysis for Model 2D

Given the above, we can conclude the following:

- **Dominance of Physical Magnitude:** The model is extremely sensitive to property area. With nearly 86% of the explained variation credited to size, even a minor measurement error in square footage would result in a large deviation. Furthermore, non-linear terms point out that this sensitivity is not constant, i.e. the model is more sensitive to size changes in small area values than in larger ones due to diminishing marginal returns, i.e. each additional square meter of property area adds less to the total transaction price than the previous square meter did.

- **Vertical Sensitivity Multiplier:** The floor level (Item_level) is the second most critical factor, explaining nearly 8% of the price variation. F-statistic (134.58) and p-value ($1.36*10^{-303}$) assures the importance of floor level of values in Agia Paraskevi, reflecting height as a mandatory increase value factor across all districts.
- **Qualitative Sensitivity (Age vs. Maintenance):** It is important to notice that the model is more sensitive to the property's specific condition ($SumSq = 15.71$) and the *interaction* between year and condition ($SumSq = 8.39$) than to the chronological construction year itself ($SumSq = 5.69$). This specifies that "effective age" is more important factor than "actual age", i.e. a renovated unit ($SumSq$ contribution) has a higher marginal impact on the price than a newer construction date.
- **Spatial and Energy Secondary Factors:** While Agia Paraskevi is divided in many districts, and energy ratings are important in the current market, micro-districts and energy ratings account for less than 1% each of the price variation. This suggests that while these factors are important to the model, they are not the main factors with respect to the physical utility of the asset. All in all, the model is effective to neighborhood shifts, meaning that a large, high-floor apartment in Pefkakia will likely still outprice a small ground-floor unit in the high-prestige College area (Passportivity, 2025).

5.2. MATLAB® PlotEffects results

The approach of plotEffects relies on the construction of an adjusted response function, which describes the relationship between a single predictor and the fitted response, with other predictors averaged over the data used in the fit.

Mathematically, suppose you have a model with p predictors, where the fitted response for the $i-th$ observation is given by $y_i = f(x_{1i}, x_{2i}, x_{3i}, \dots x_{pi})$, the adjusted response function $g(x_1)$ for a predictor x_1 is defined as the average of the fitted values across n observations:

$$g(x_1) = \frac{1}{n}\sum_{i=1}^{n} f\left(x_1,\ x_{2i}, x_{3i}, \dots x_{pi}\ \right)$$

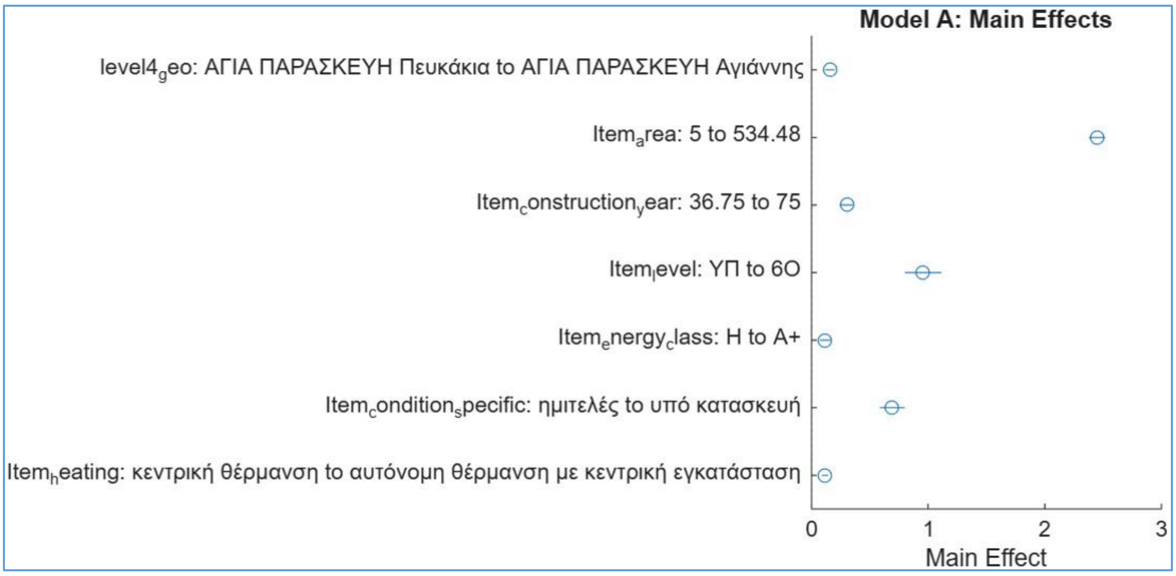

Figure 2: PlotEffects – Model 2A

The "Main Effect" of the predictor x_s is visualized in the provided figures (Models A–E) represents the difference $g(x_{si}) - g(x_{sj})$. For categorical predictors, MATLAB® selects the levels i and$j$ that yield the maximum and minimum adjusted responses, respectively, ensuring the effect is always positive for standardized comparison. For numeric predictors, the function chooses the minimum and maximum values within the predictor's range to illustrate the total swing in the response variable across that interval. This methodology provides a standardized metric of sensitivity, allowing researchers to compare the relative impact of unequal/inequivalent variables such as square footage, floor level, and energy efficiency on a uniform scale.

The horizontal lines in the plotEffects results define the magnitude of sensitivity of the model: if the lines are short suggest that the model is highly sensitive to these variables and that the estimated effects are robust across the dataset like Item_area and Item_level across in all five images. In contrast, some predictors present extensive confidence intervals indicating that the model is less certain about the exact impact of these predictors, due to higher variance in the data or a smaller number of observations for these specific categories.

Additionally, the level4_geo effect (e.g., Pefkakia to Stavros) present small magnitudes and wider confidence intervals compared to other factors, meaning that model's sensitivity to geography is less certain than its sensitivity other factors like physical attributes.

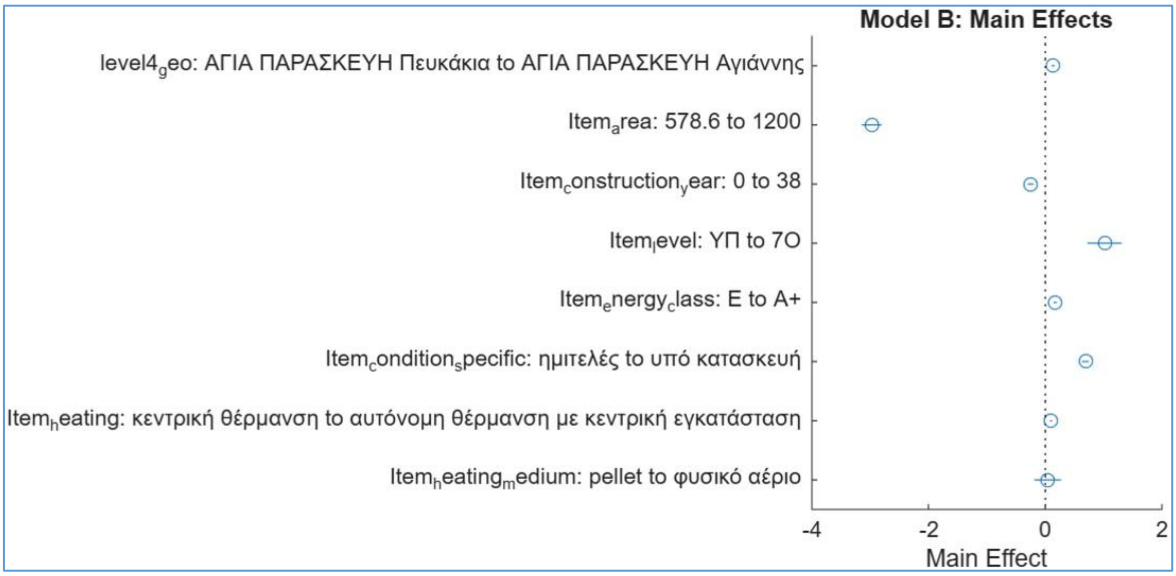

Figure 3: PlotEffects – Model 2B

Relevant Figures (Figure 2-Figure 6) show a steady grading of importance among the predictors, where property attributes prevail over geographic and infrastructural variables in terms of effecting scale.

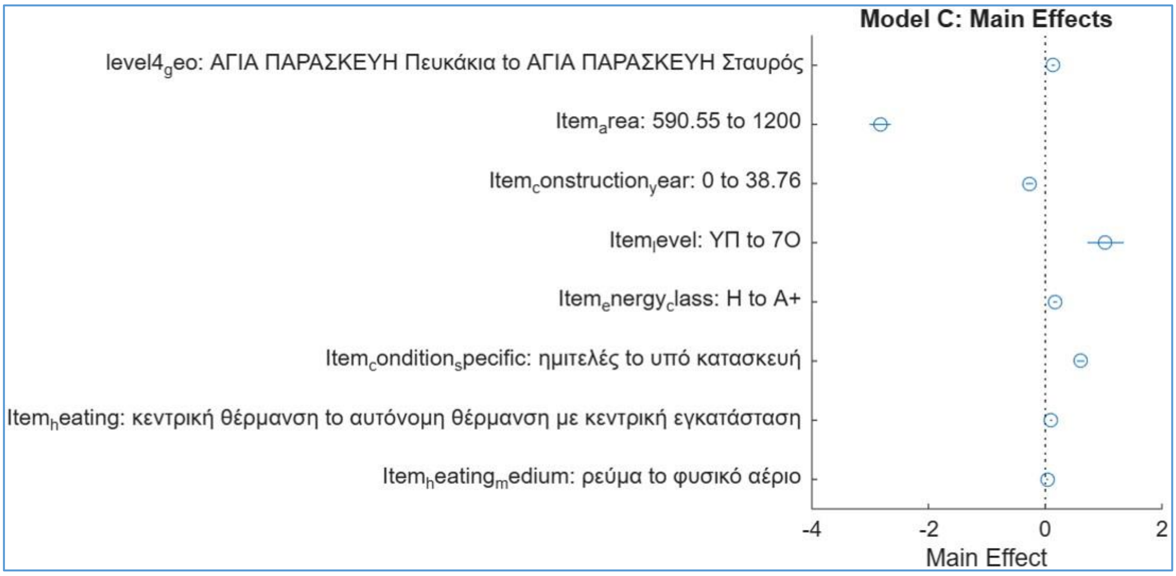

Figure 4: PlotEffects – Model 2C

The results confirm that location is a secondary driver as can be observed from the top of the y-axis, since its total magnitude is eclipsed by the area variable, while the most outstanding insight from Figure 2-Figure 6 is the signal inversion of sensitivity to Item_area depending on the property size range:

- In Models A and D, where the property area is less than 500 square meters, a positive effect (Figure 2, Figure 5) is observed, indicating that this factor is the most powerful driver of price growth.
- In Models B, C, and E, where property areas range from 580 to 1,200 square meters, the area presents a negative main effect (Figure 3, Figure 4, Figure 6). This indicates the negative marginal impact of additional space.

Furthermore, the **Item_level** predictor exhibits a major positive main effect constantly for all levels around 1.1-1.2 for all models (Figure 2, Figure 5). with very tight confidence intervals (Figure 3, Figure 4, Figure 6). Floor level appears to be one of the most stable and significant predictors in the Agia Paraskevi market, due to the narrow confidence intervals.

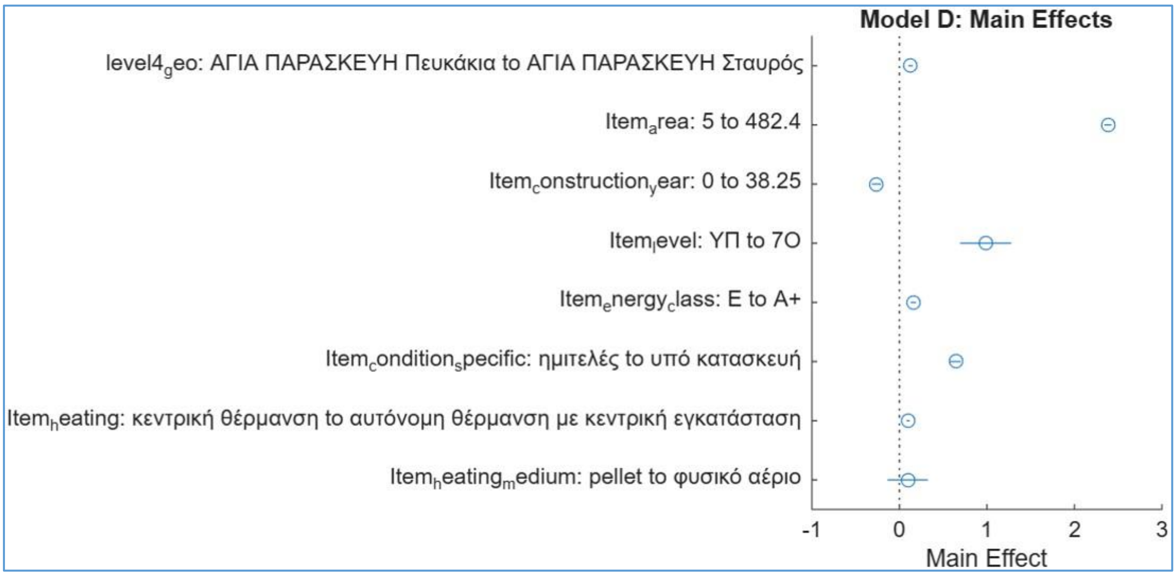

Figure 5: PlotEffects – Model 2D

The condition of the property consistently shows a positive main effect (Figure 2, Figure 5). This designates that after the area and the floor level, the condition of the property is a primary driver of value. Likewise, Construction year shows a smaller positive impact across most models (Figure 2, Figure 3, Figure 5).

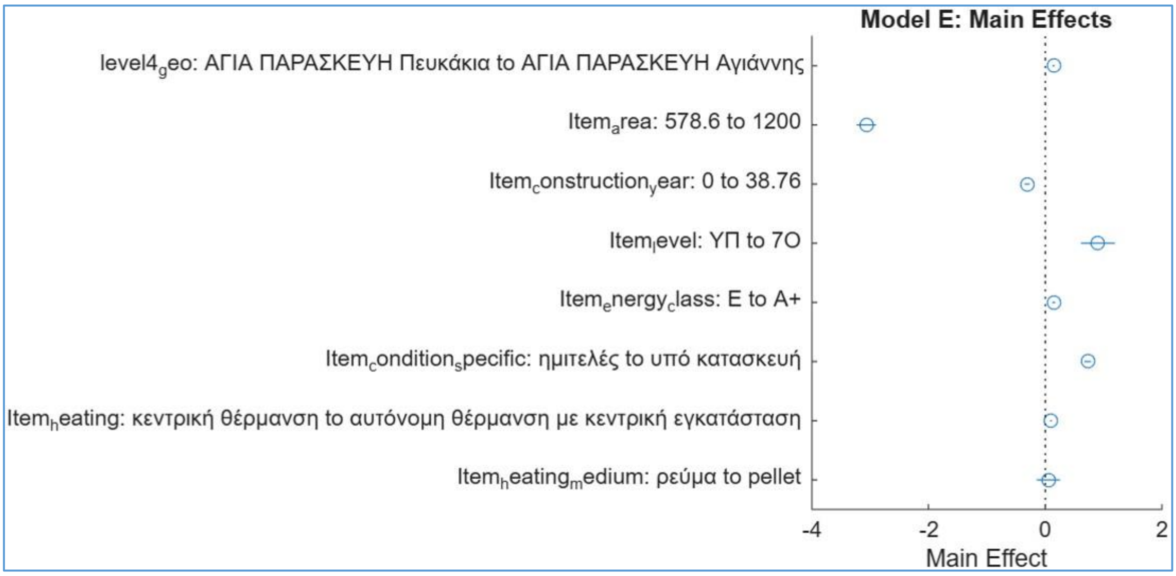

Figure 6: PlotEffects – Model 2E

5.3. MATLAB® PlotAdded results

The sensitivity analysis conducted herein relies on the mathematical framework of partial regression, also known as the Frisch-Waugh-Lovell Theorem. In a multilinear environment, a simple scatter plot of a predictor against the response often produces misleading results due to the confounding effects of other predictors. The added variable plot (AVP) overcomes this by "netting out" the influence of all other covariates (Cook & Weisberg, 1982).

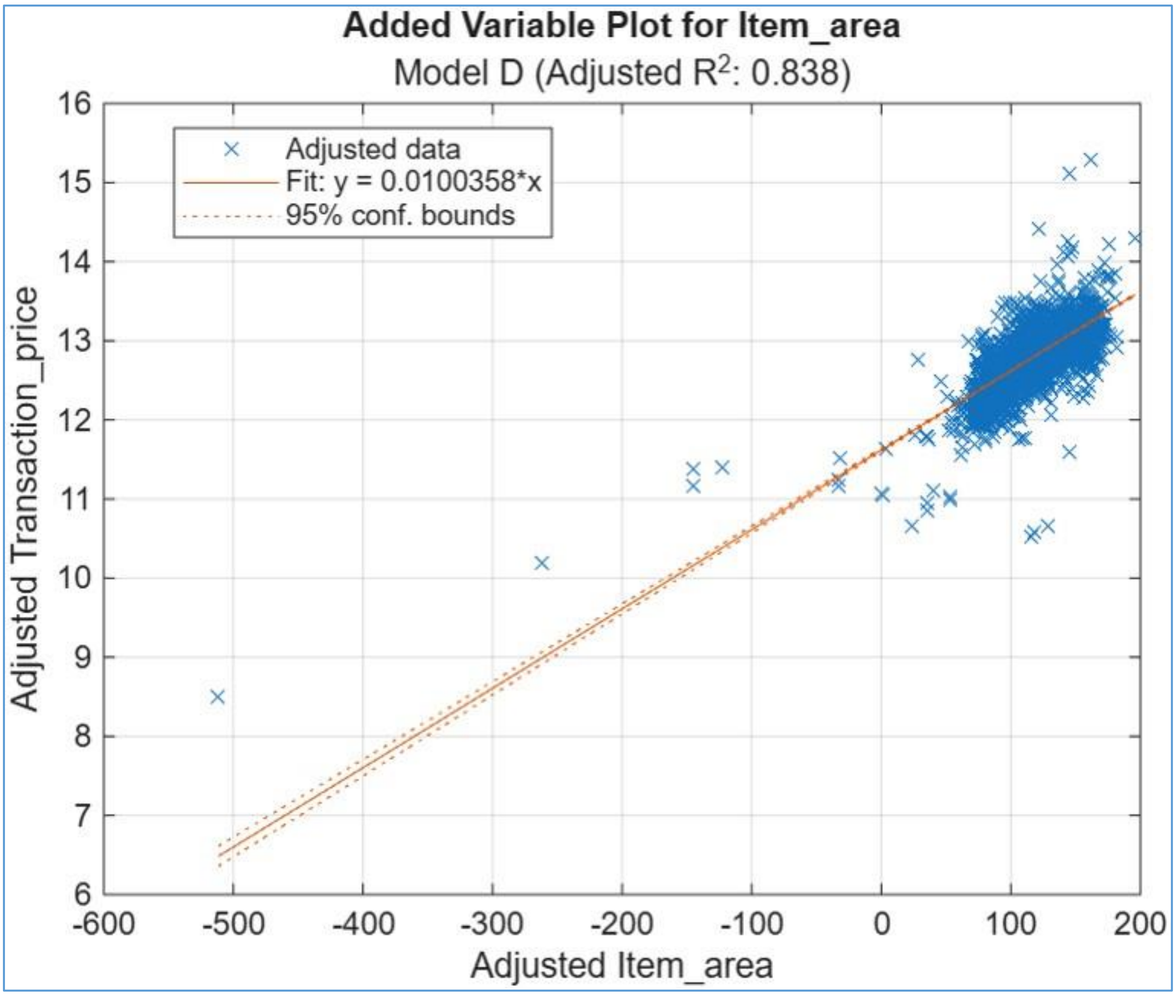

Figure 7: Added variable plot – Model 2D – Item Area

To visualize the unique sensitivity of the transaction price to a single predictor, such as Item_area, MATLAB® performs a two-stage regression process. First, the response variable is regressed against all predictors in the model except the one under investigation. The resulting residuals, represent the portion of the transaction price that remains unexplained by the other variables. Second, the predictor of interest is regressed against the same set of remaining predictors to yield residuals. These residuals capture the unique information provided by that is not already redundant with other terms in the model.

The added variable plot displays these residuals, typically shifted by their respective means to maintain a familiar scale. The adjusted predictor values ($\tilde{x}$) and adjusted response values ($\tilde{y}$) are defined as follows:

$$\tilde{x}_i = r_{xi} + \bar{x}$$

$$\tilde{y}_i = r_{yi} + \bar{y}$$

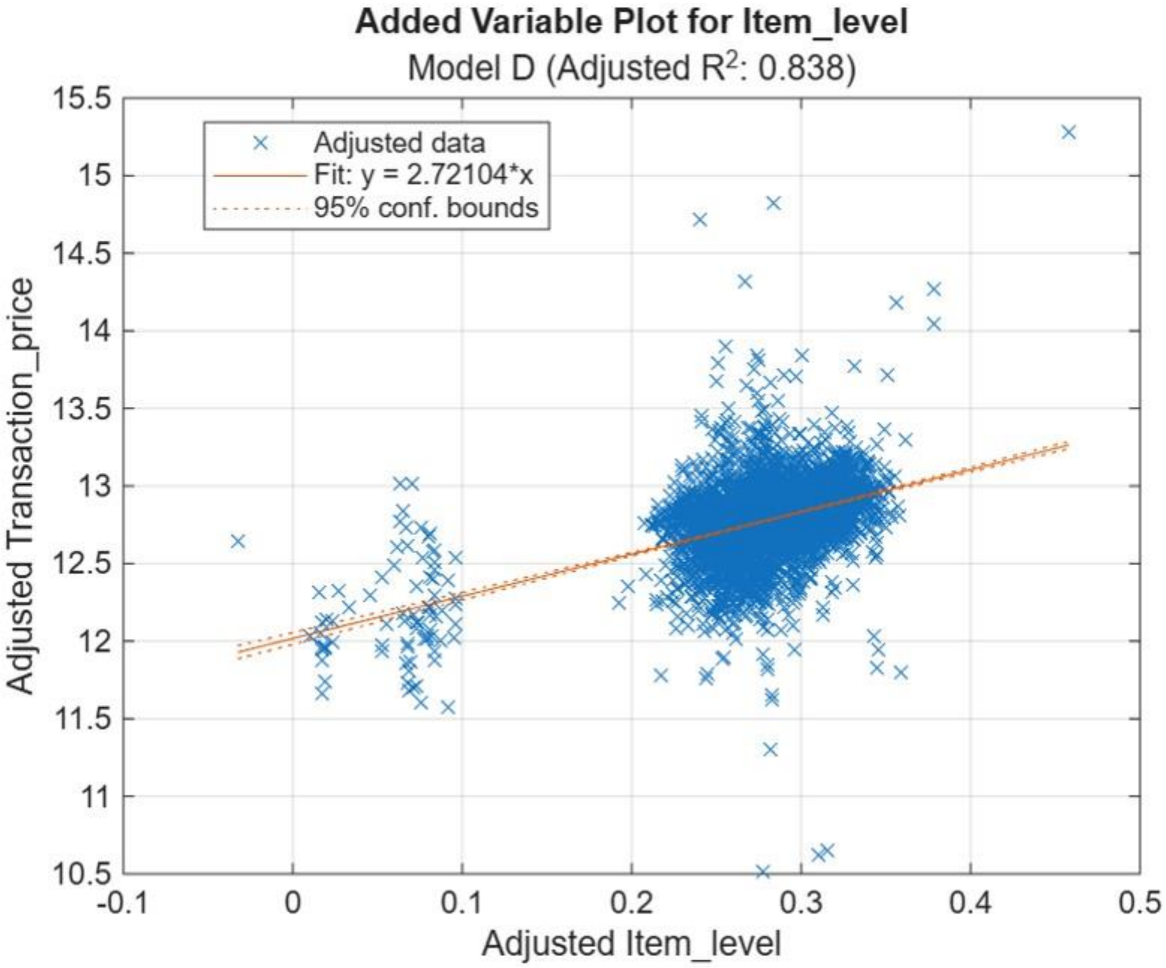

Figure 8: Added variable plot – Model 2D – Item level

Where $\bar{x}$ and $\bar{y}$ are the sample means of the predictor and response. The slope of the line of best fit through these adjusted points is mathematically identical to the regression coefficient β_1 found in the full multilinear model. Subsequently, the magnitude of the slope is a direct graphical and numerical indicator of the variable's sensitivity for each model.

An important aspect of these plots is the dotted lines expressing the 95% confidence intervals which define the uncertainty of the slope line of the fit. Then statistical significance of the predictor is ensured if and only if the dotted excludes horizontal lines, i.e. lines where sensitivity is null. Then predictor is considered significant at the $\alpha = 0.05$ level (Cook & Weisberg, 1982).

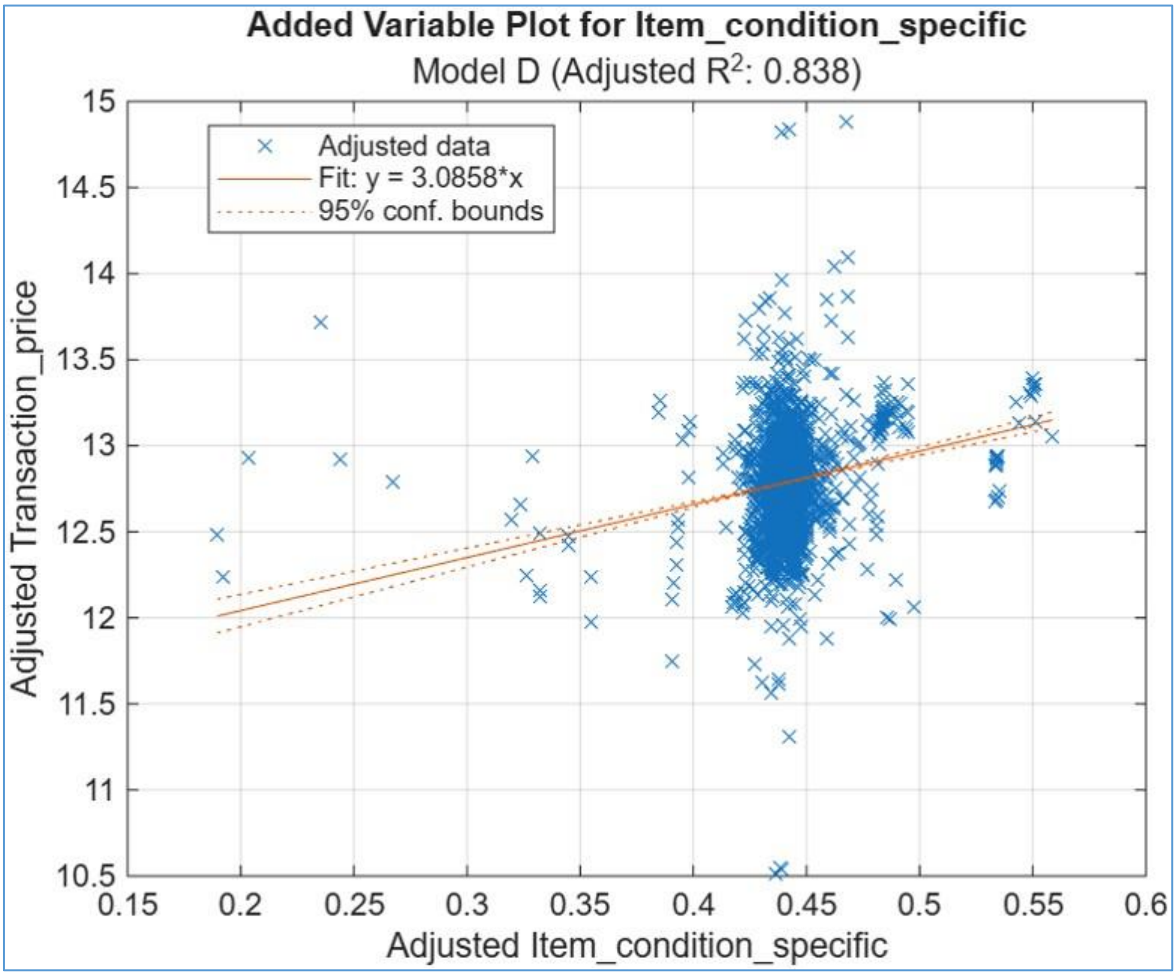

Figure 9: Added variable plot – Model 2D – Item condition specific

The width of the confidence bounds in the added variable plots is a proxy for the stability of the sensitivity estimates. When two predictors are highly correlated, the r_x residuals (the x-axis values in the AVP) become very small, effectively "squashing" the data toward the center of the plot. In Model D, the variables Item_heating and Item_heating_medium present this kind of behavior, which may indicate a degree of collinearity between these predictors. Additionally, as already mentioned, the presence of outliers and high-leverage points can bias sensitivity estimates, like point -500 in the area plot. This means that results may improve if these points are removed (Cook & Weisberg, 1982). Similarly, several plots (e.g. Floor level and Energy class) show vertical outliers, which can be removed for improved results.

5.3.1. Detailed Analysis of Model 2D Predictor Sensitivity

As already discussed, Model 2D illustrates a high-performing model with satisfactory Adjusted R^2 of 0.838, having approximately 83.8% of the variance explained by the included predictors. Sensitivity to individual variables is evidenced in the following Table 18.

Predictor Variable	**Regression Fit Equation (Adjusted)**	**Relative Sensitivity**	**Visual Significance**
Item_level	$y = 2.72104 * x$	High	Significant
Item_area	$y = 0.0100358 * x$	Very Low (per unit)	Significant (High Range)
Item_condition_specific	$y = 3.0858 * x$	Very High	Significant
Item_construction_year	$y = 0.00226719 * x$	Negligible	Non-Significant
Item_energy_class	$y = 0.323305 * x$	Moderate	Significant
Item_heating	$y = 0.104085 * x$	Low	Significant
Item_heating_medium	$y = 0.0993176 * x$	Low	Marginal

level4_geo	$y = 0.159902 * x$	Moderate-Low	Significant

Table 18: Slopes in the added variable plots

Except of the slope values, sensitivity should be interpreted with respect to the range of the predictor, e.g. even if Area (Figure 7) variable has a fitted slope is 0.0100358. The slope appears small, and the variable's adjusted range spans from approximately -500 to +200 units. This means that a 100-unit increase in adjusted area corresponds to a 1.00-unit increase in the adjusted transaction price that represents a massive change in a logarithmic scale. Thus, given that the plot shows a strong linear effect and the confidence bounds are tight, Area is significant in price sensitivity.

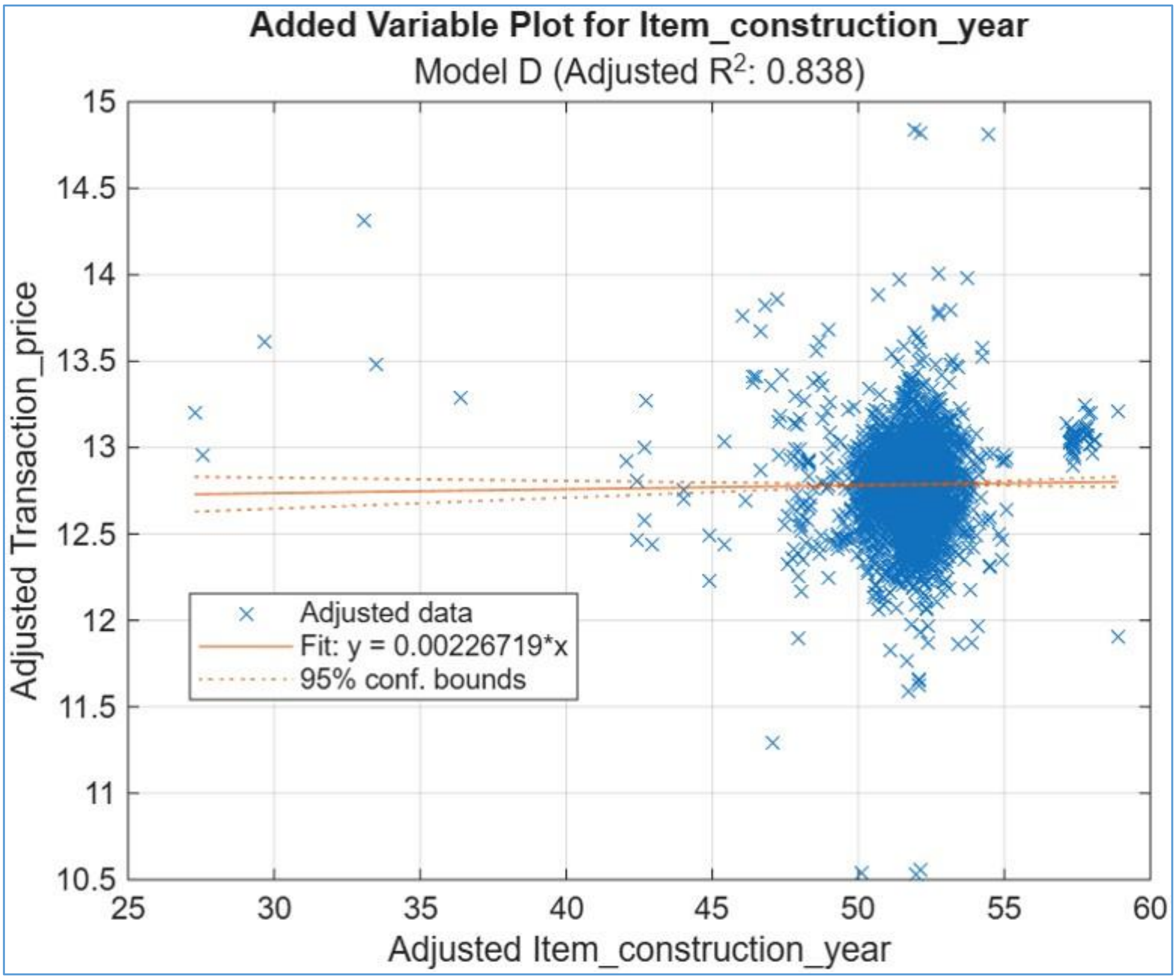

Figure 10: Added variable plot – Model 2D – Item Construction year

In the same vein, floor level (Figure 8) presents a steeper slope of 2.72104 which suggests that the model is extremely sensitive to changes in the "level" attribute. The data points present two clusters: one around 0.05 and around 0.3. Even if the slope is steep, given that the adjusted range is small (approximately -0.05 to 0.45), changes will be limited. The concentration of data points suggests that the model's estimate for intermediate floor levels values might not be supported by empirical results.

The variable condition (Figure 9) shows the highest slope and thus the highest sensitivity of 3.0858. Most of the adjusted data points appear near 0.45, which is translated that most of the data have a similar "condition". This observation states that sensitivity estimate is efficient for "typical" conditions but not consistent for extreme values.

The slope for the construction year (Figure 10) is nearly zero (0.00226719), while the visual representation do not shows a linear trend, which means that the specific year of construction has almost no marginal impact on the transaction price for Model D. Thus, improved results suggest exclusion of this variable can be excluded from the model without losing explanatory power.

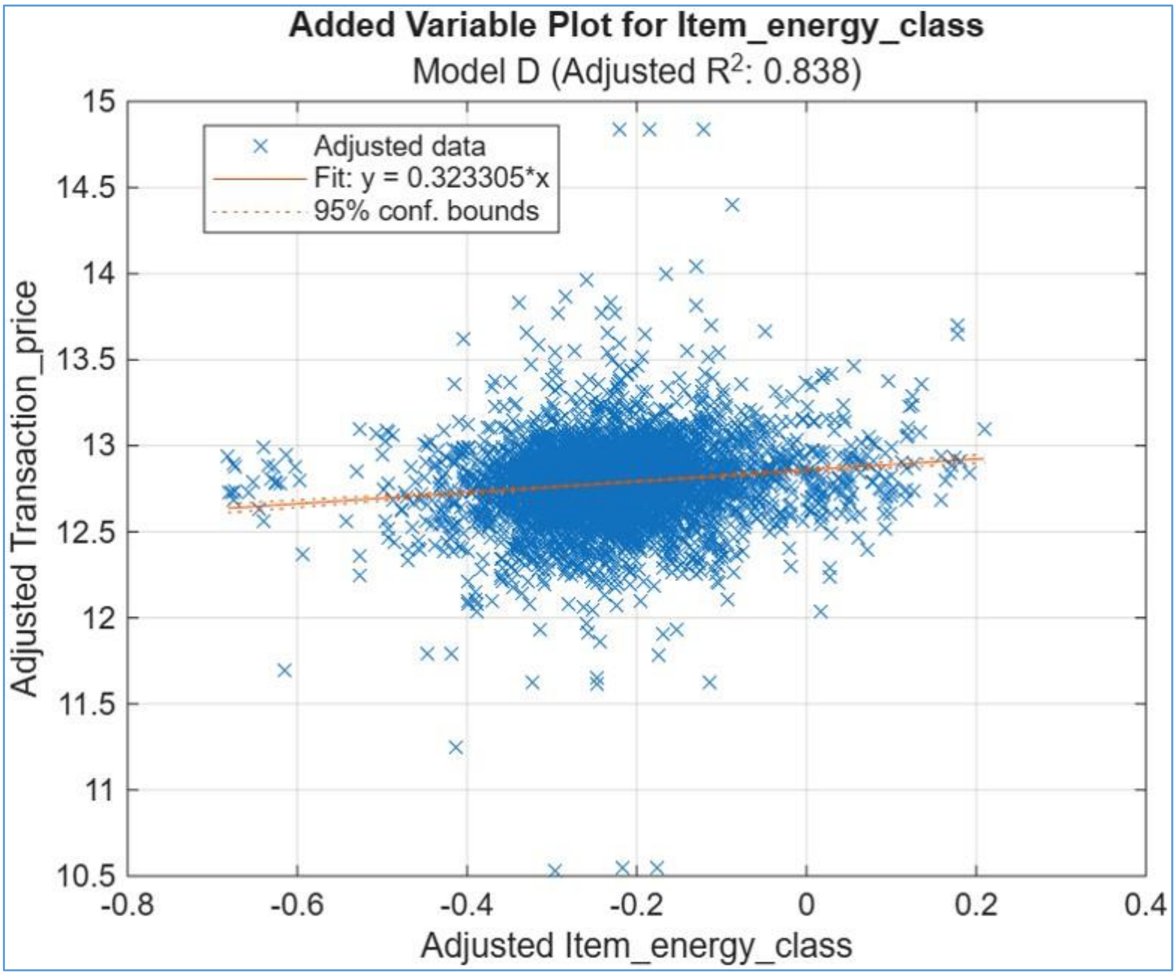

Figure 11: Added variable plot – Model 2D – Item energy class

Energy and heat are important for contemporary buyers. Energy class (Figure 11) shows a moderate positive slope of 0.323305 . The uniform spread of adjusted data in the x-axis, suggests well-established connectivity of higher energy efficiency correlates with higher transaction prices. Additionally, both Item_heating (Figure 12, Figure 13) and Item_heating_medium having slopes of 0.104 and 0.099 respectively show that heating methods and mediums are less influential than physical attributes , while their confidence bounds also indicate higher uncertainty.

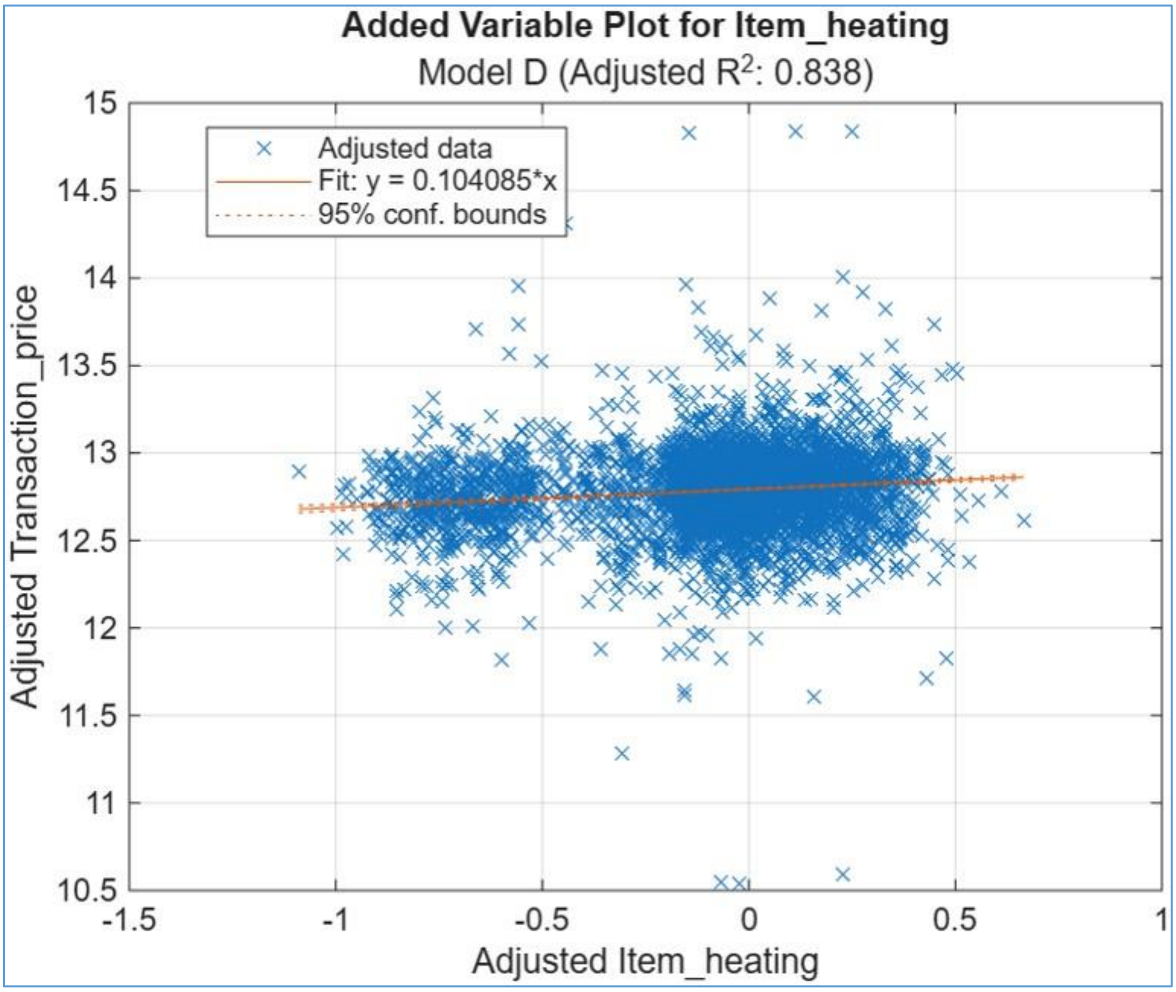

Figure 12: Added variable plot – Model 2D – Item heating

Finally, Figure 14 represents the neighborhood effect of the 2D model. Having a slope of 0.159902, location has an intermediate impact. The plot displays two clusters of adjusted values, likely representing two primary regions or clusters of locations. Results prove that, local price variation is secondary to other factors physical factors.

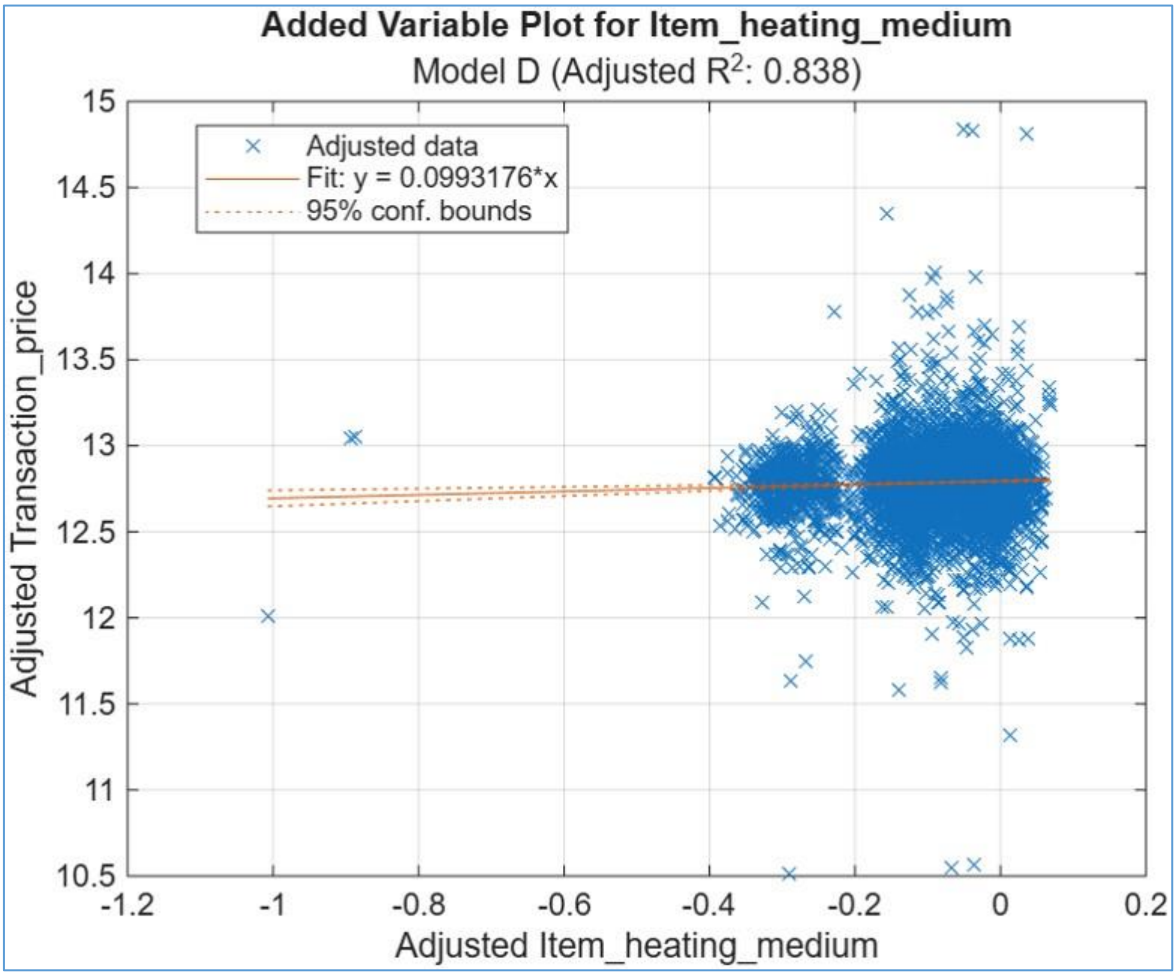

Figure 13: Added variable plot – Model 2D – Item heating medium

All in all, while slopes in Model D's AVPs represent the *incremental* effect of each variable the *total* potential impact of a variable across its entire range, e.g. although Condition has a higher slope (3.08) than Item_area (0.01), Item_area varies over a range of 700 units, while condition varies over a range of only 0.4 units. This means that while condition is more sensitive "per unit," Area is the dominant driver of price variation in the overall dataset due to its much larger scale as imprinted in the total potential (Table 19) .

Predictor	**Range of Adjusted Predictor (Δx~)**	**Slope (β)**	**Total Potential Impact (β·Δx~)**

Item_area	~700	0.0100	7.00
Item_level	~0.5	2.7210	1.36
Item_condition	~0.4	3.0858	1.23
Item_energy_class	~1.0	0.3233	0.32

Table 19: Total potential impact estimations

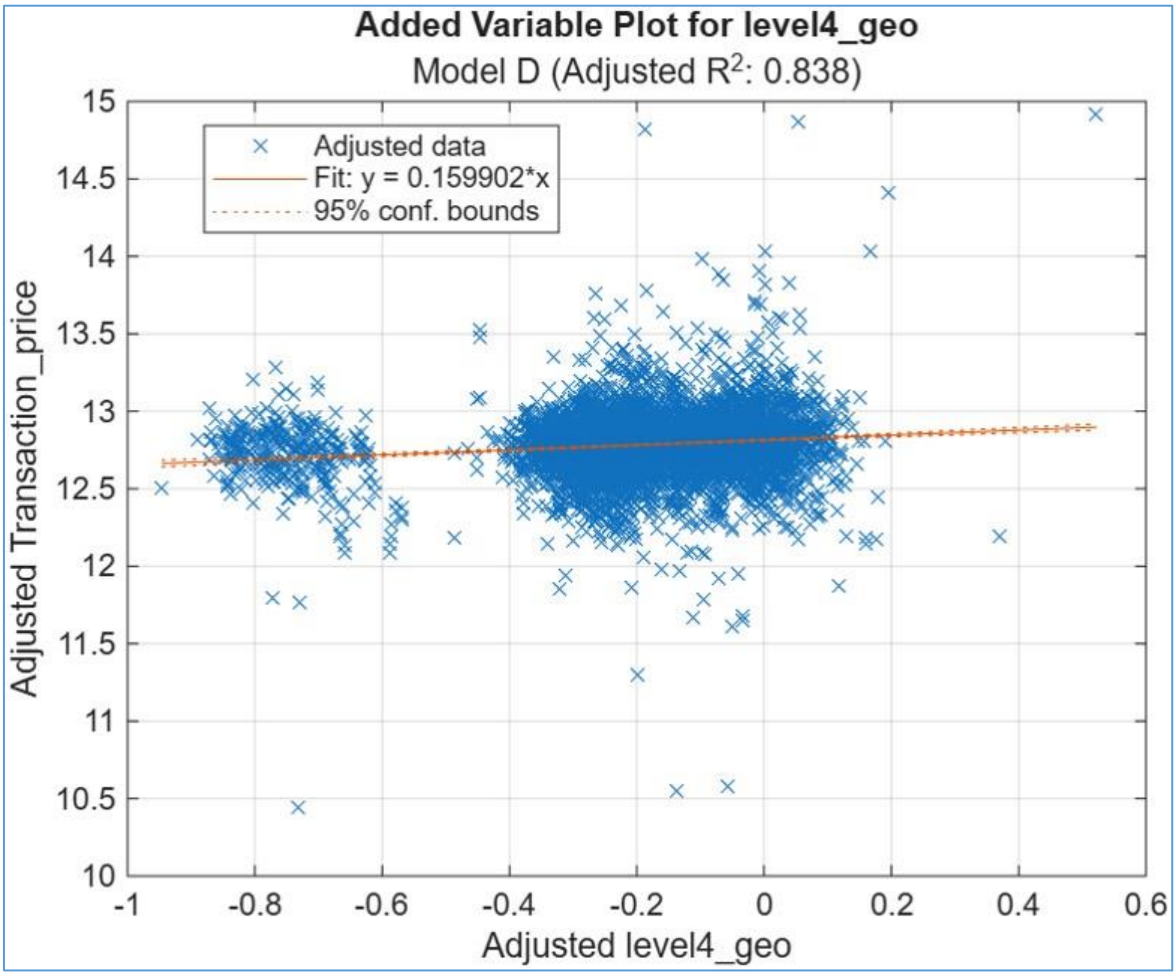

Figure 14: Added variable plot – Model 2D – Item Neighborhood

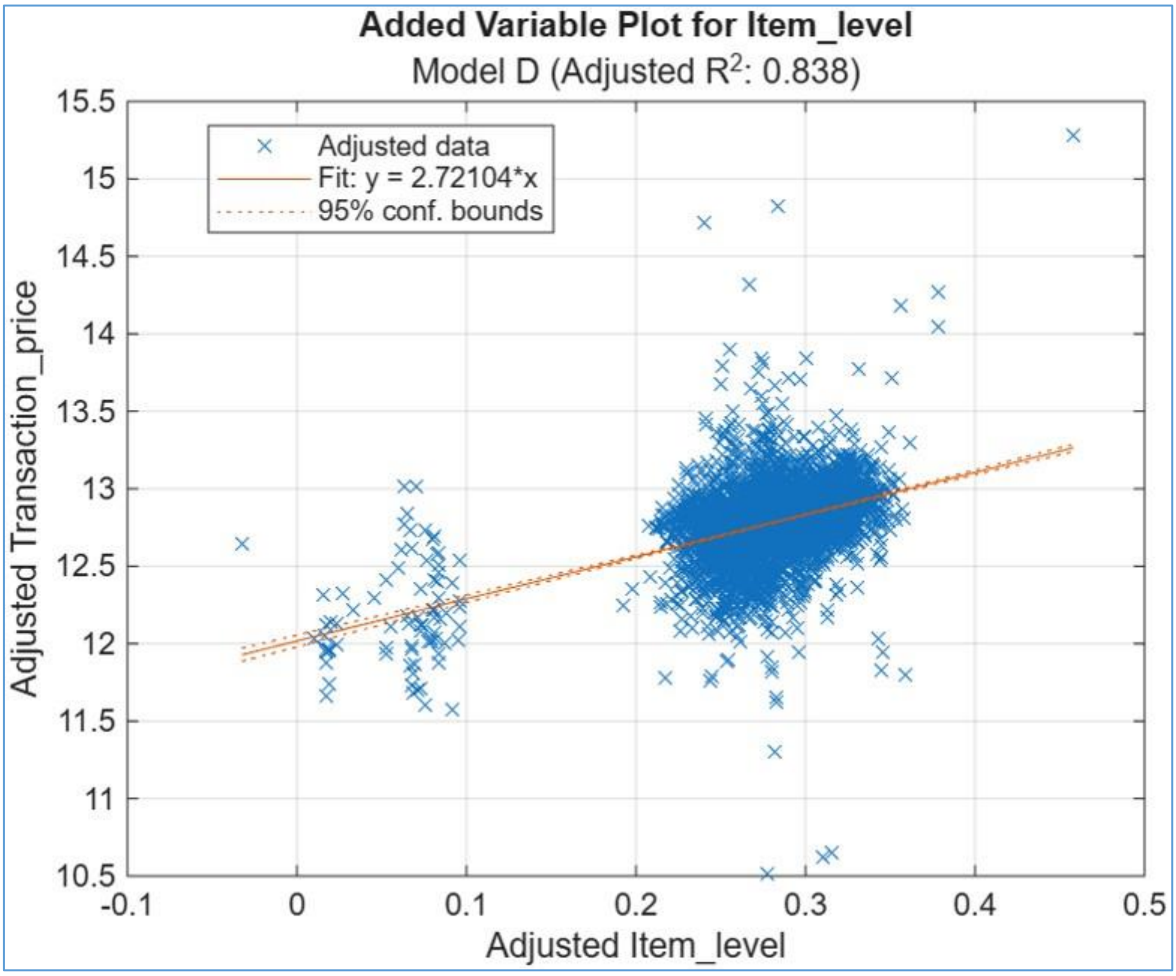

Figure 15: Added variable plot – Model 2D – Item level

5.4. MATLAB® PlotPartialDependence results

PlotPartialDependence function, is a global technique which visualizes how the expected value of the model's prediction changes as a function of one or two input features. https://www.mathworks.com/help/stats/regressiontree.plotpartialdependence.html.
Additionally, is supplemented by Individual Conditional Expectation (ICE) plots, which correspond in the following plots to grey thin lines. The interpretation of the plots are described in the following Table 20.

Visual Component	Color/Style	Definition and Functional Role
PlotPartialDependence Curve	Bold Orange Line	Represents the marginal effect of the feature on the predicted Transaction_price. It indicates the

		global sensitivity of the model to that specific variable
ICE Curves	Thin Grey Lines	Represent the predicted response for each individual observation. They reveal heterogeneity and potential interaction effects
Predicted Observations	Black Circles	A scatter plot overlaying the predicted responses for the actual data points. This shows the actual distribution of predicted values across the feature range
Response Variable	Y-Axis	Labeled Transaction_price. Given the range (approx. 11 to 14.5), this represents a log-transformed price to handle variance and skewness (Faraway, 2006).
Predictor Variable	X-Axis	The feature under investigation, which can be continuous (e.g., area) or categorical (e.g., heating medium)

Table 20: Interpretation of PlotPartialDependence results

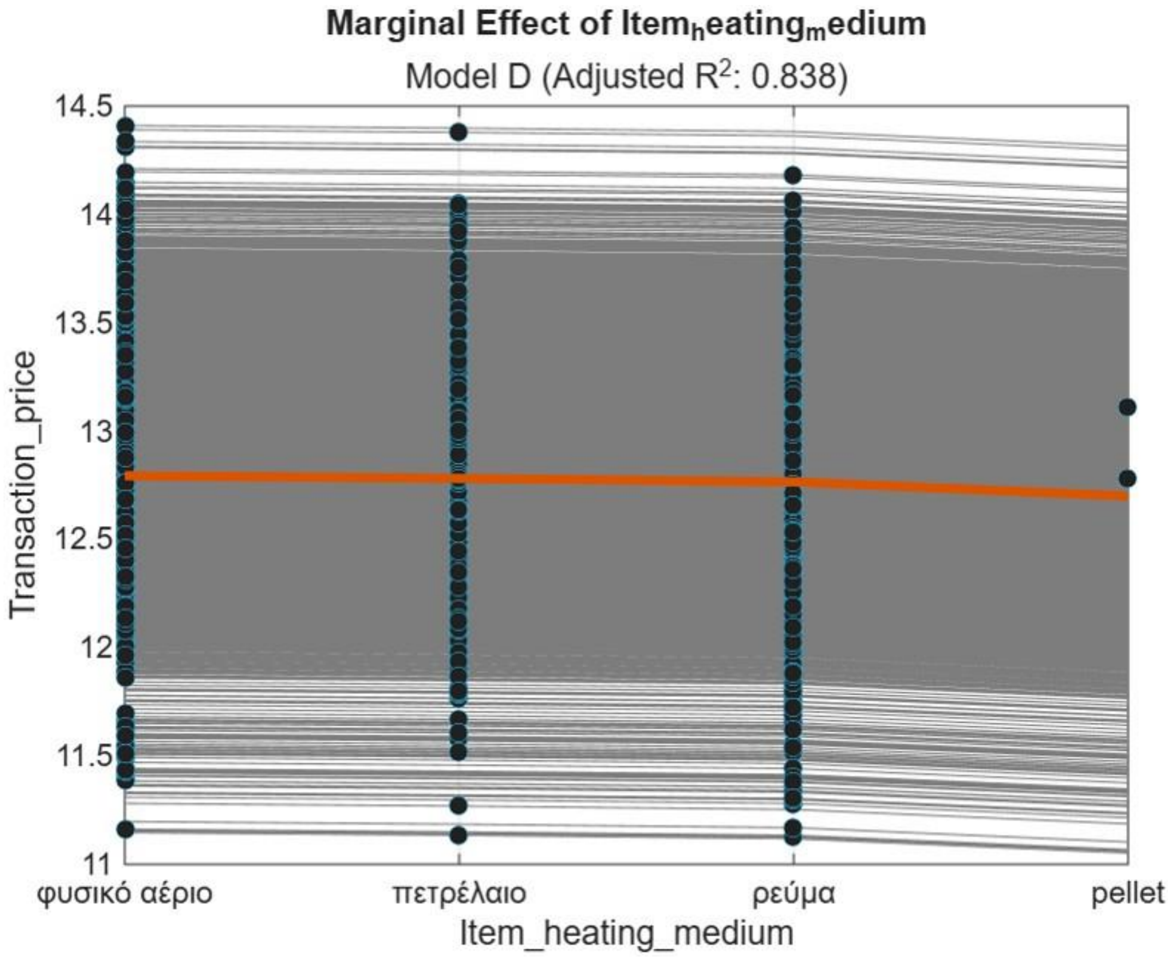

Figure 16: PlotPartialDependence – Item Heating Medium

Figure 16 focuses on Item_heating_medium, while Figure 17 explores Item_heating. The Greek categories include:

- **φυσικό αέριο (Natural Gas):** It is an efficient utility in urban centers
- **πετρέλαιο (Heating Oil):** It is the traditional standard, with reduced market share
- **ρεύμα (Electricity):** Modern systems like heat pumps are included in this option
- **pellet (Biomass):** An alternative renewable source

In both Figure 16 and Figure 17, the orange plotPartialDependence line is remarkably flat across all categories exhibiting low sensitivity to the specific type of heating and its mediums.

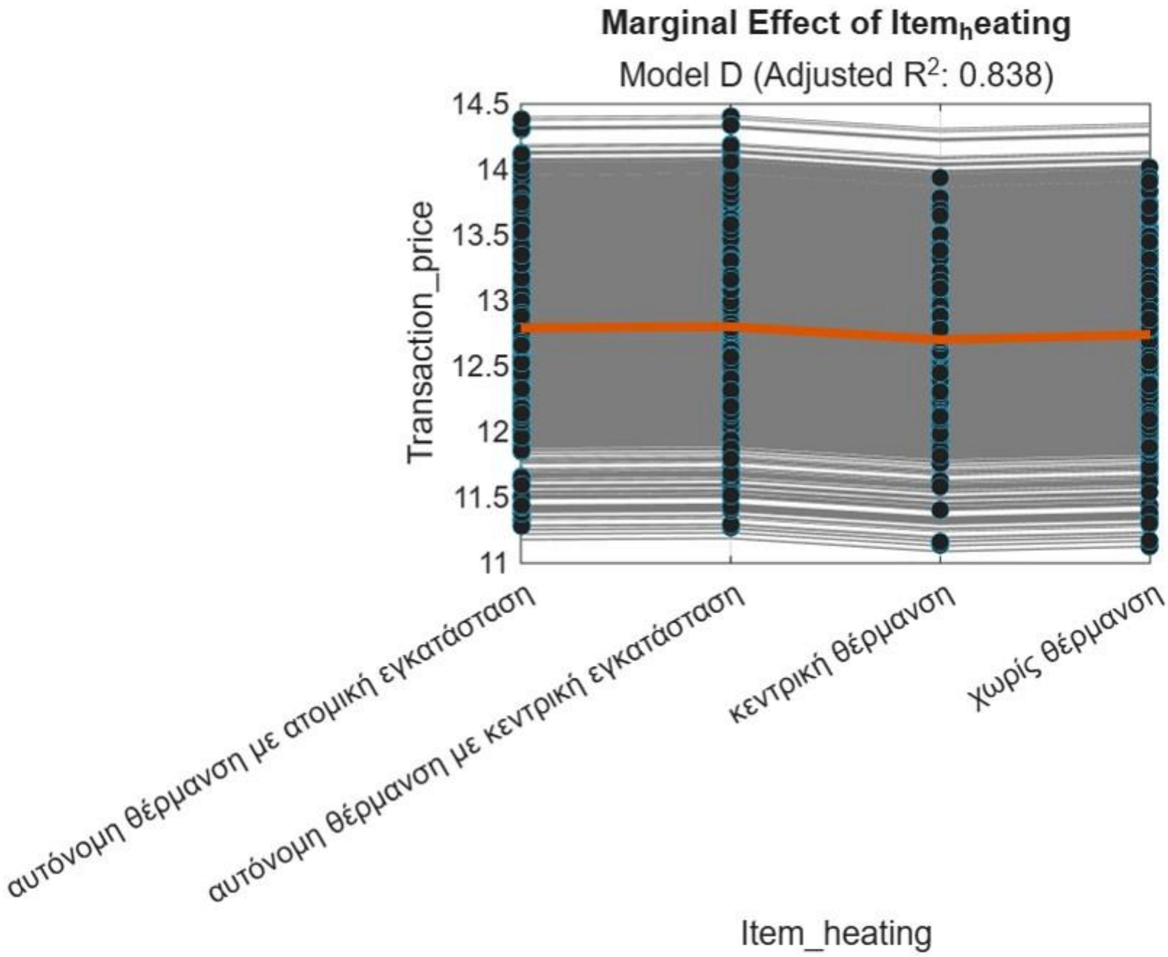

Figure 17: PlotPartialDependence – Item Heating

Figure 18 displays the marginal effect of Energy class, ranging from (A+) to (H) and presents a slight downward trend which suggests the secondary impact of the variable.

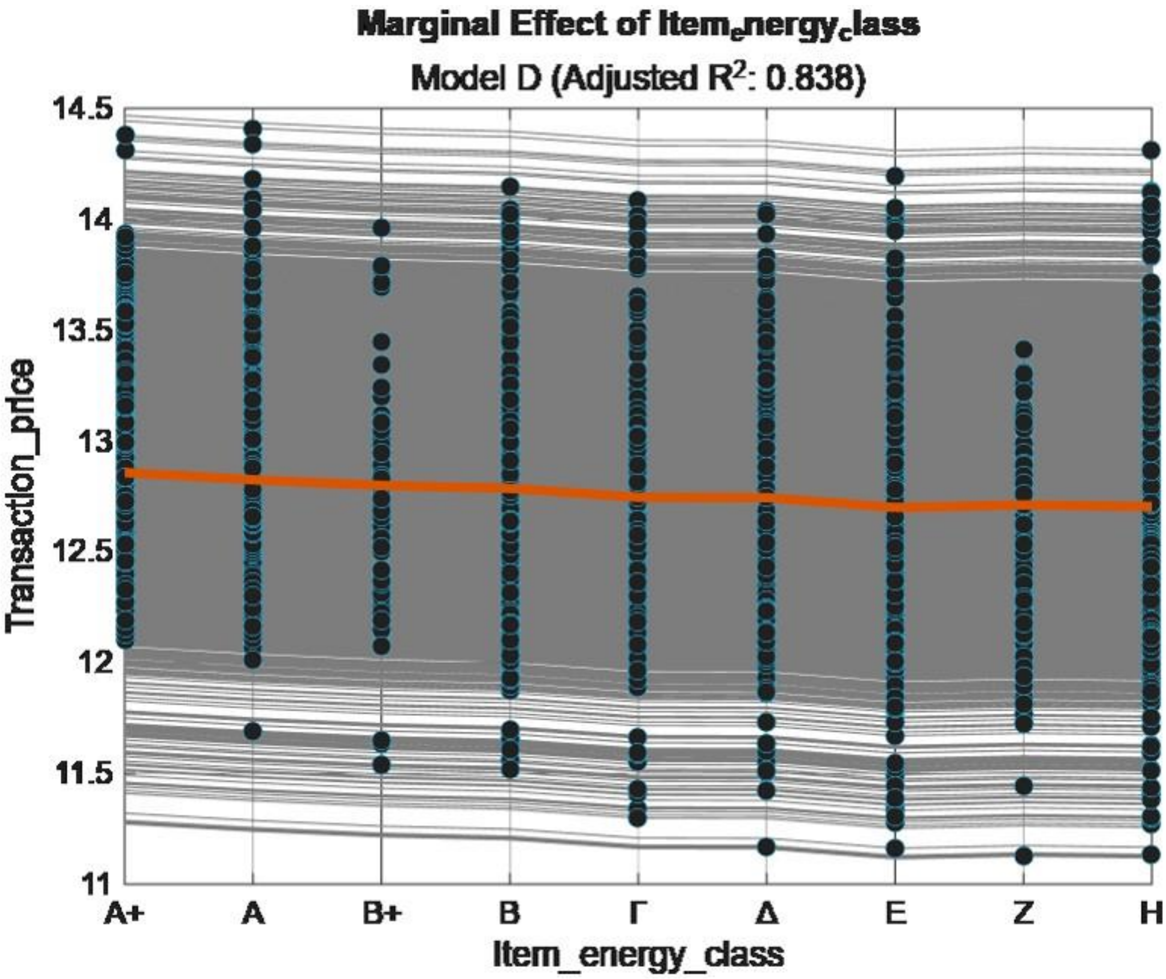

Figure 18: PlotPartialDependence – Item Energy Class

Figure 19 explores the geography effect, referring to specific neighborhoods (e.g., Κοντόπευκο, Πευκάκια). The lines are almost flat which indicate either neighborhood homogeneity of prices or that structural characteristics are more important to differentiate prices in this area (Büyükkaraciğan, 2021).

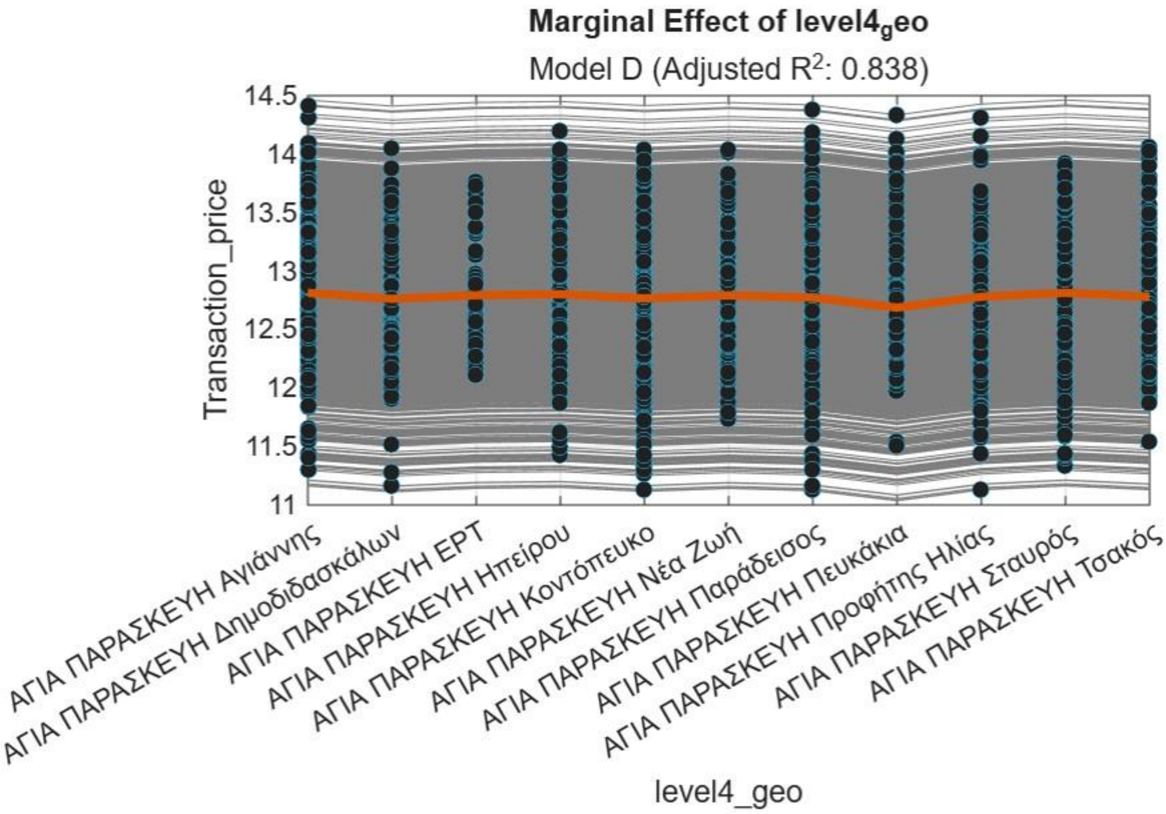

Figure 19: PlotPartialDependence – Item Level4_geo – Neighborhood effect

In contrast to the above considerations, the orange line in Figure 20 shows a steep upward incline from basement to ground floor (IS), confirming the high sensitivity of the variable capturing the market preference. Notice that 7th floor has very few values in the dataset.

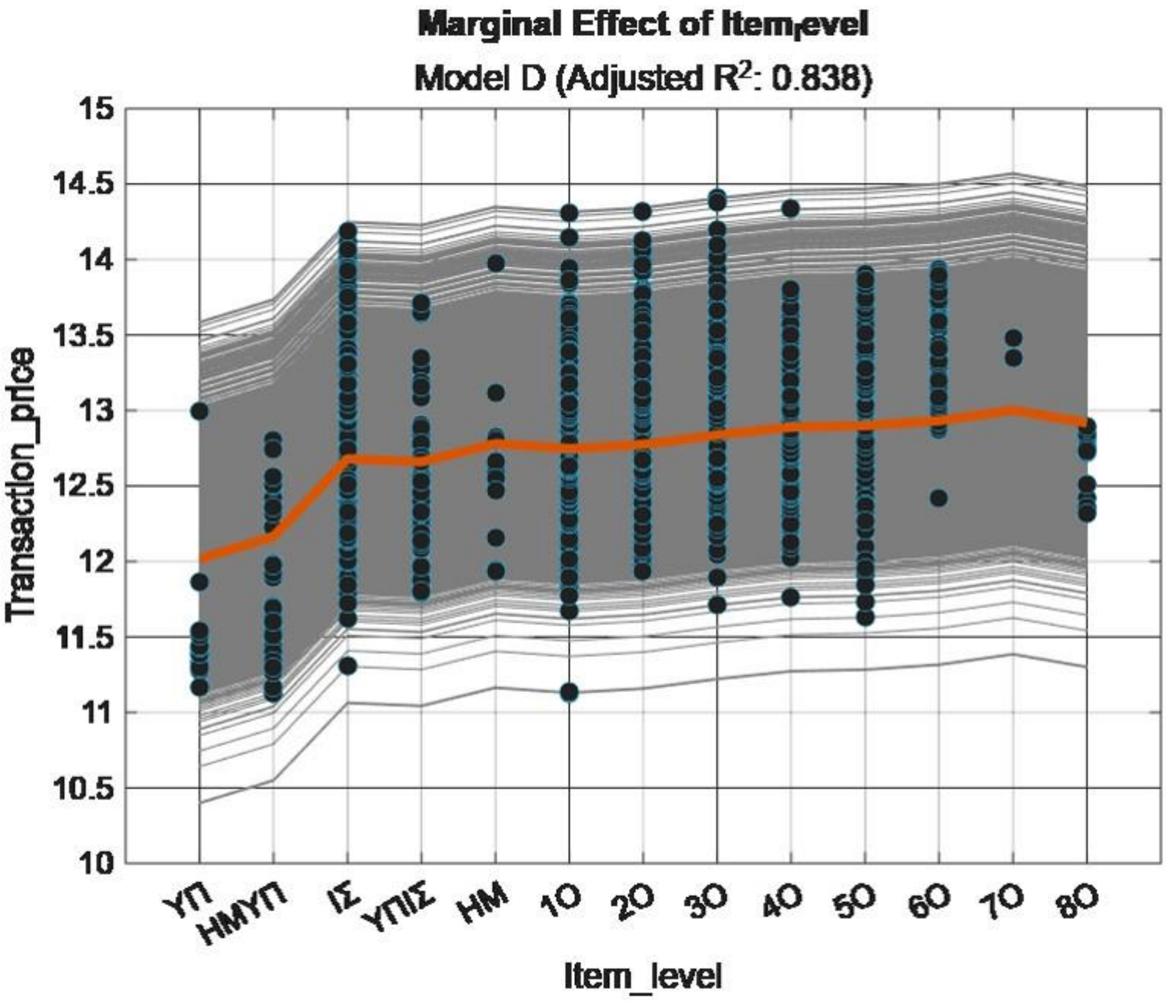

Figure 20: PlotPartialDependence – Item_Level

An extremely important issue concerning the visualization of nonlinearity of the area variable is presented in Figure 22, depicting the importance of the. The orange line follows a clear parabolic (inverted U-shape) path defined as follows:

- **Phase 1 (0–450 sqm):** Price increases almost linearly with area.
- **Phase 2 (450–550 sqm):** The curve flattens, indicating null sensitivity of the area.
- **Phase 3 (> 550 sqm):** Price decreases almost linearly with area The curve declines, likely reflecting lower price-per-square-meter.

Notice finally that outliers discussed in previous paragraphs dominate the third phase and an improved model could consider remove them.

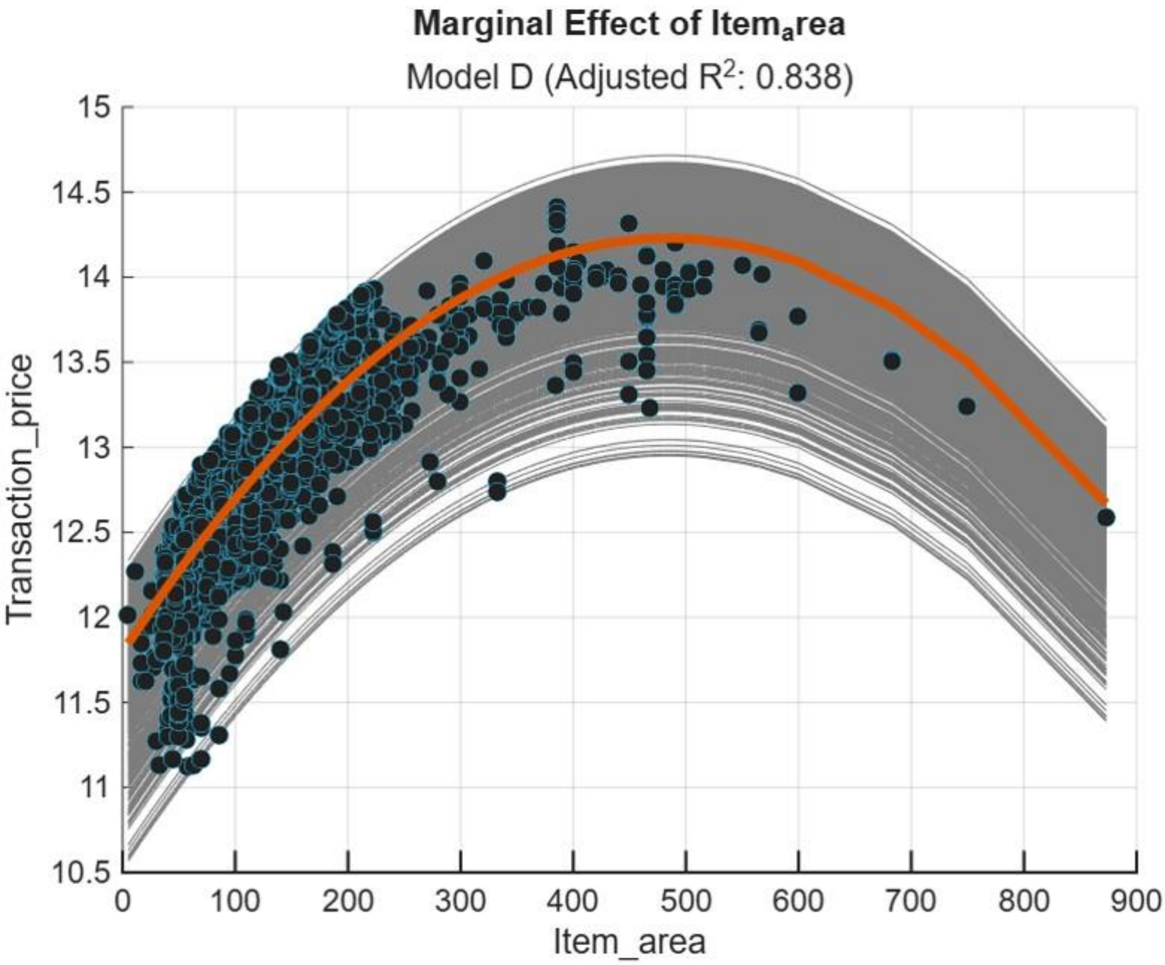

Figure 21: PlotPartialDependence – Item Area

Figure 22 shows Construction year (likely represented as age since 0 is the value of a property constructed in 1950). The very shallow U-shaped curve can be also interpreted as a flat line, which confirms results from previous sensitivity analysis and suggests the lack of importance of the predictor with respect to other variables. Furthermore, it can be easily observed a lack of new construction, almost between years 60-70, i.e. during years of crisis 2010-2020.

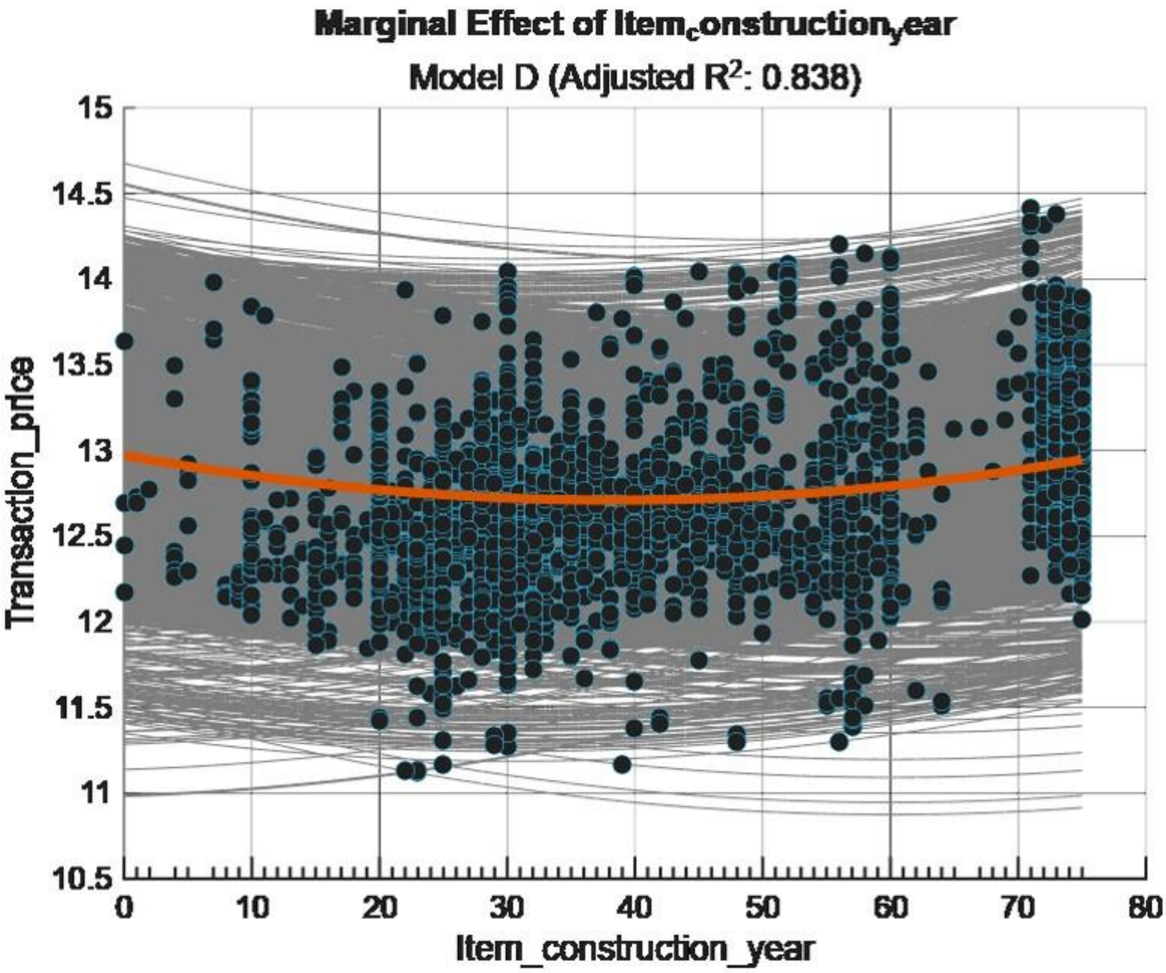

Figure 22: PlotPartialDependence – Item Construction Year

Following the results concerning construction year, Figure 23 displays results for Condition showing a lifecycle from incomplete (ημιτελές) to newly built (νεόδμητο). The sensitivity analysis quantifies the “renovation gap”, i.e. the vertical distance between "needs renovation" (χρήζει ανακαίνισης) and "renovated" (ανακαινισμένο) on the orange line quantifies the average value added by a comprehensive renovation (Büyükkaraciğan, 2021) as well as the equal importance of a renovated with a newly built property.

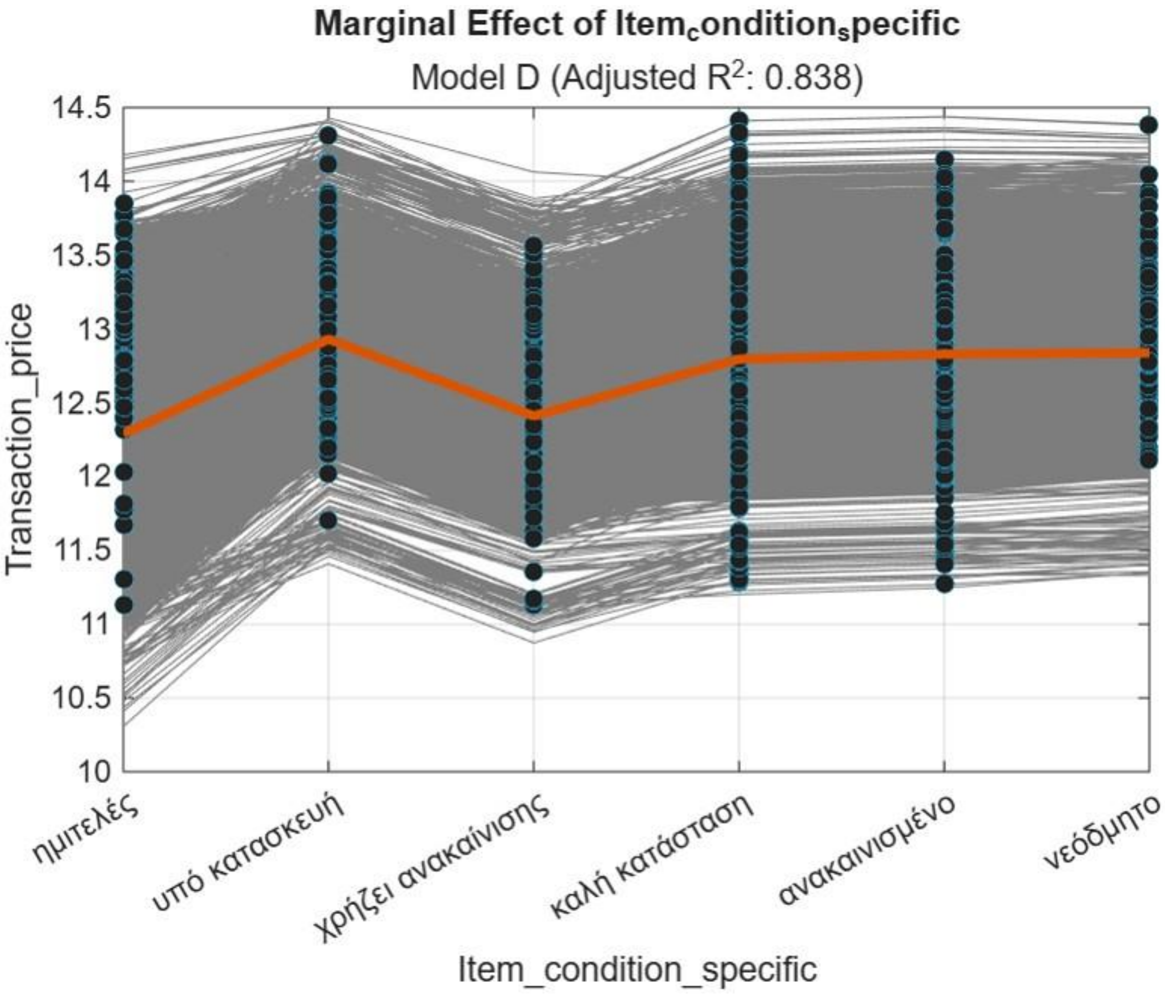

Figure 23: PlotPartialDependence – Item Condition specific

5.5. Sobol' indices

Figure 24, Figure 25, Figure 26, Figure 27 and Figure 29 provide the core sensitivity analysis results, presenting both direct impact (S_i) and total impact (ST_i), partitioning the importance of various physical and geographical attributes.

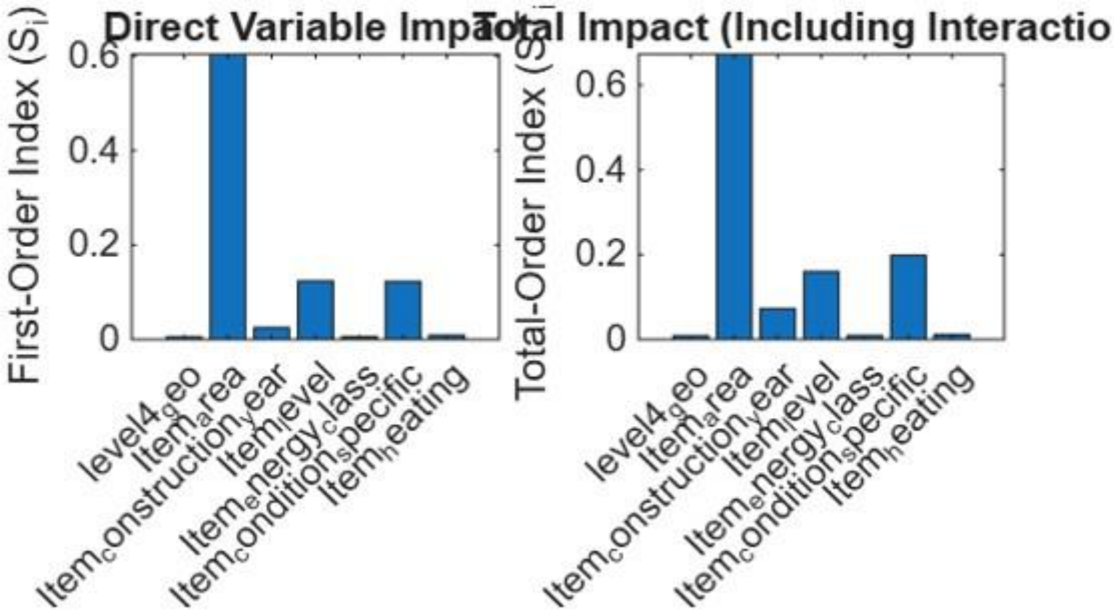

Figure 24: Sobol' indices – ModelA

5.5.1. Dominance of Property Area

Again, as already established in previous iterations, (Figure 24 - Figure 29), Area emerges as the primary variable since its first-order index (S_i) is consistently near 0.6 and 0.7, while its total-order index (ST_i) nears 0.7-0.8. The slight gap between S_i and ST_i for area suggests that while size is the main factor, its effect is moderately influenced by other variables, such as floor level or condition, (Saltelli et al., 2010; Prieur & Tarantola, 2017).

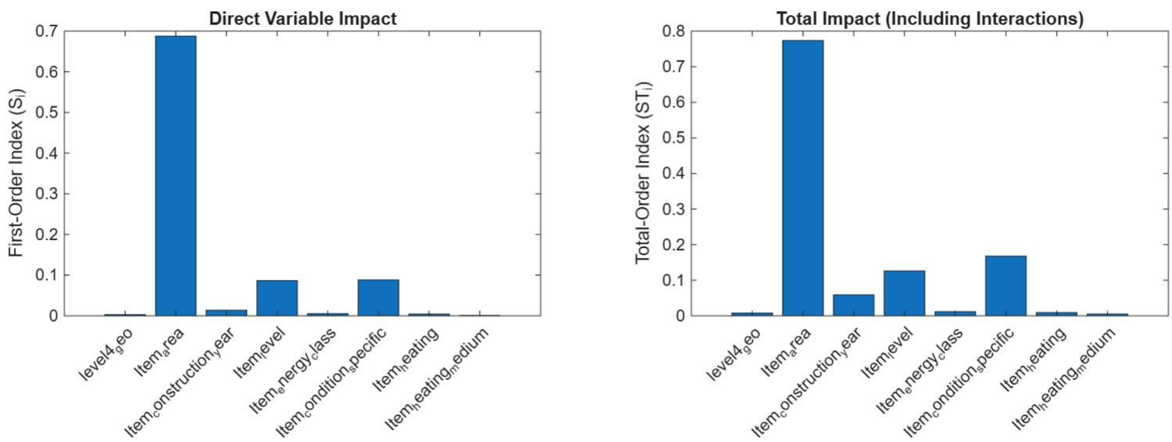

Figure 25: Sobol' indices – Model B

5.5.2. Secondary Factors and Interaction Effects

The variables "Item_level" and "Item_condition_specific" appear as the next most significant factors. In Figure 27 and "Item_condition_specific" shows a ST_i of approximately 0.20, which is higher than its S_i of roughly 0.125. This difference signifies that the "condition" of the property is related to other features, such as its energy class (Sudret, 2008; Saltelli et al., 2010).

Variable Name	**Direct Impact (Si)**	**Total Impact (STi)**	**Interaction Magnitude (STi - Si)**
Item_area	~0.612	~0.685	~0.073
Item_level	~0.115	~0.150	~0.035
Item_condition_specific	~0.125	~0.200	~0.075
Item_construction_year	~0.018	~0.070	~0.052
Item_energy_class	~0.008	~0.008	~0.000

Table 21: Local and Global Sobol indices for the predictors – Model 2D

The low sensitivity indices for "Item_energy_class" in the global variance decomposition contrast with the large "Price Impact per Level" coefficients (Figure 28). This is a common phenomenon in GSA: while a variable may have a large effect on the output (large coefficient), if its variance in the dataset is small or if other variables (like area) are overwhelmingly more varied, its contribution to the *total output variance* will be low (Sobol, 1993). This suggests that while energy class matters for the price of an individual home, the overall spread of prices in the market is driven much more by size and location.

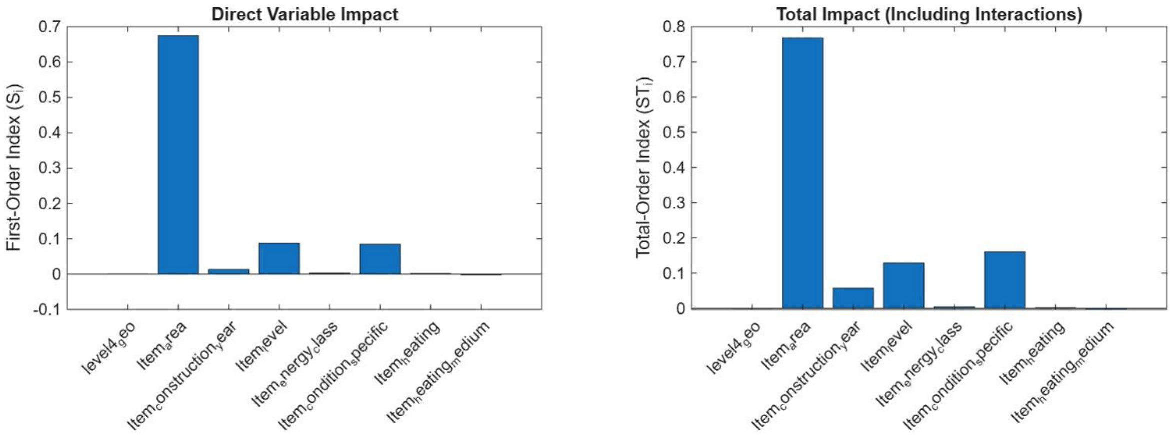

Figure 26: Sobol' indices – Model C

5.5.3. Identifying Non-Influential Variables for Factor Fixing

Variables such as "level4_geo," "Item_heating," and "Item_heating_medium" show near-zero values for both S_i and ST_i in several figures. In the context of GSA, this identifies these variables as candidates for "factor fixing" (Saltelli et al., 2010) and its exclusion improves the model by reducing variables of the input space (Iooss & Lemaıtre, 2014).

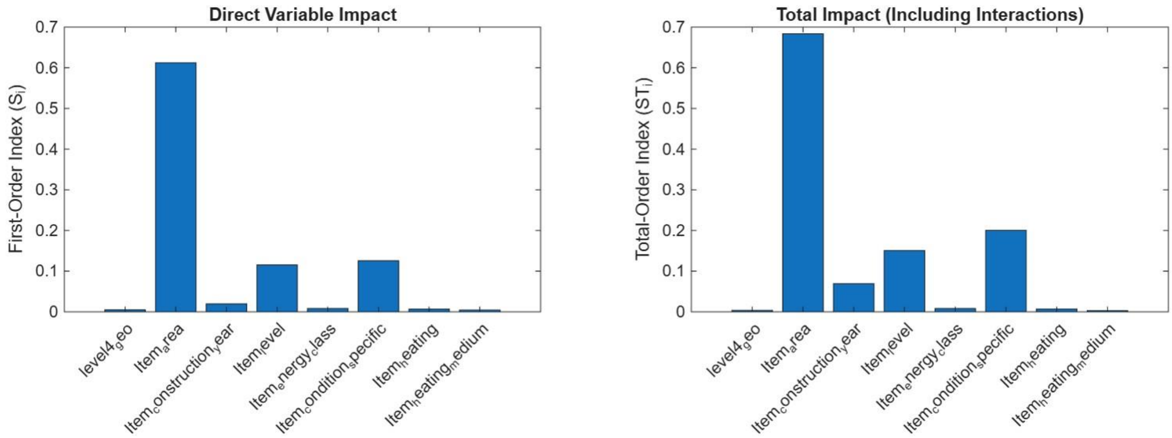

Figure 27: Sobol' indices – Model D

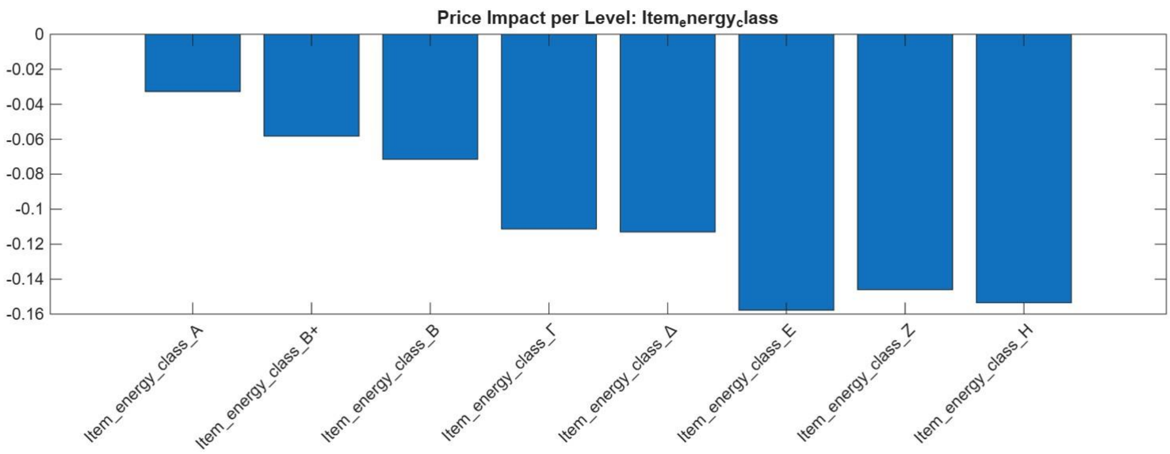

Figure 28: Model D – Sobol' indices for the Ordinal variable

All in all, the Sobol indices addressed additional issues concerning the importance of the predictors: while "Item_energy_class" has a lower global sensitivity index, its categorical impact on price is substantial and negative for lower-tier efficiency ratings (Classes Γ to H, Figure 28). This indicates that energy efficiency is a "quality benchmark" rather than the primary source of market-wide price spread (Vecchiato et al., 2026).

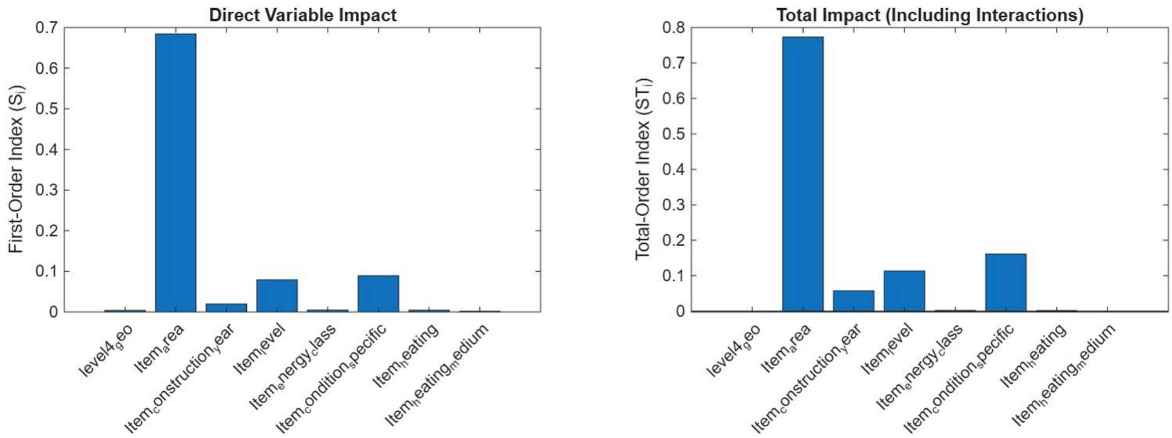

Figure 29: Sobol' indices – Model E

6. Discussion and Recommendations

6.1. Statistical Architecture and Computational Robustness of Automated Valuation Models

The above described work provides an extensive analysis of the factors of residential property values in Agia Paraskevi, exploiting a dataset provided by GOLDEN DEAL S.M.S.A. (2025). Hedonic regression models and complex sensitivity analyses were performed via MATLAB©, to identify the predictors that drive market dynamics (Sudret, 2008). The dependent variable used in the Ordinary Least Squares (OLS) estimator was the natural logarithm of the transaction price (Schulz et al., 2019).

Five distinct deduplication categories (A–E) were tested, ranging from simple coordinate matching to complex filters incorporating area and price (Table 8). The models were also divided into three Tiers: Model 1 (full data cases), Model 2 (some processing and updating of existing data), and Model 3 (synthesized data based on market assumptions). Model 2D, which utilizes identical coordinates and transaction prices as the deduplication filter, was the most efficient model, providing an Adjusted R^2 of 0.838 and a highly competitive Mean Absolute Percentage Error (MAPE) of 13.92% (Ecker et al., 2020).

Computational stability, however, proved to be a significant constraint for the Model tier 1 and 3. The results recognizes sparsity of data in categorical variables as the main cause of model instabilities. When e.g. a specific floor level in a specific neighborhood jointed by a rare energy class, have insufficient observations with respect to the number of predictors and dummy variables, the resulting design matrix becomes ill-conditioned. The RCOND was used as the diagnostic for this issue. In contrast to Model tier 1 and 3, for Model 2D, the RCOND value ensures computational stability of the model.

6.2. Data Taxonomy and Characterization

The dataset includes 11,865 observations with 111 distinct parameters, capturing a time frame from February 2021 to September 2025. The area was the municipality of Agia Paraskevi, which is subdivided into the following neighborhoods: Kontopefko, Nea Zoi, Tsakos, Stavros, Aigiannis, Pefkakia, Profitis Ilias, Dimodidaskalon, Ipirou, ERT, and Paradeisos (Lin & Chen, 2022).

The parameters of the dataset can be are classified into: a. structural attributes, b. construction related factors, c. utility and infrastructure parameters and d. amenity-specific factors and fully described in Table 22. Starting form this high-dimensional approach the important variables influencing the price are optimized by minimizing the residual variance in price (Indomio, 2026).

Parameter Cluster	**Representative Variables**	**Analytical Role**
Core Dimensions	Item_area, Item_total_area, Item_bedrooms	Primary drivers of total transaction price .
Chronological/Quality	Item_construction_year, Item_refurbishment_year, Item_condition_specific	Captures depreciation and effective age premiums (Winson-Geideman et al., 2008).
Vertical/Spatial	Item_level, level4_geo, lng, lat	Determines height premiums and neighborhood effects (Lin & Chen, 2022, Matysiak, 2022).
Energy/Infrastructure	Item_energy_class, Item_heating, Item_heating_medium	Reflects regulatory compliance and operational costs (BPIE, 2018).

Amenities/Security	Item_has_parking, Item_has_secure_door, Item_has_elevator	Marginal value-added components .

Table 22: Clustering predictors

6.3. Data Reliability and Multi-Stage Validation Protocols

Given that data was obtained from advertisements, data quality is doubted by the occurrence of multiple listings: owners may involve several agents and brokers, same agents change constantly postings of the same property by introducing slight perturbations in variables to achieve interest etc. Accordingly, the first step of the research focused on data valuation, reliability, and deduplication. To evaluate the impact of data quality on model performance, five distinct deduplication strategies were implemented. Then the administration of null values across the dataset was considered and the different approaches - also described in 4.1.4 - produced the Model tiers 1,2,3. Finally, a total of 15 data models was defined; the number of data for each one is described in Table 8. This procedure suggested that over-deduplication (as seen in Type A) might lead to significant reduction in sample size, whereas Type B or Type D provide a more efficient to assess and remove clear duplicates while preserving unique units within identical structures.

The synthetic data for Model Group 3 relied on the energy shift of Agia Paraskevi towards contemporary energy standards as described in 4.1.5 based on Greek Energy Performance Regulation for Buildings (KENAK) mandates and Natural Gas introduction in the area under consideration (BPIE, 2018).

6.4. Econometric Modeling Framework and MATLAB Implementation

The models were solved using the MATLAB Statistics and Machine Learning Toolbox. In particular, the stepwiselm function, an automated model selection procedure was implemented and adjusted. Computational stability was ensured by introducing the RCOND. While Model Group 1 and Model Group 3 occasionally triggered warnings presenting instability issues due to data sparsity or "badly scaled" variables, Model Group 2 remained consistently stable. In particular, Model 2D, representing properties deduplicated by location and transaction price, emerged as the most robust specification, achieving the lowest Mean Absolute Percentage Error (MAPE) of 13.92%.

The initial regression models introduced initially linear terms. Improvements included quadratic interactions to describe non-linear relationships, such as the “Area paradox” of the property size. Another important aspect captured from the non-linear models were the interaction term between construction year and property condition which defined the "effective age" concept, where renovation can significantly replace in valuation the natural depreciation of older structures (Winson-Geideman et al., 2008).

6.5. Statistical analysis of the prediction and the predictors

6.5.1. Property area

The dominant predictor across all model results was property area; their relationship is non-linear and the inclusion of the quadratic term reveals the “Area paradox”, which suggests the use of area as a parameter instead of considering as a dependent parameter the normalized "price per square meter" used in the market (Sirmans et al., 2005). Some market interpretation of this concept is presented in Table 23.

Size Category	**Estimated Price Impact per Unit Area**	**Market Liquidity and Demand Profile**
Compact (20–50 sqm)	Highest (+10.5% growth)	Driven by students, professionals, and investors (Elxis, 2025).
Medium (51–110 sqm)	Moderate	Standard family units; the bulk of the market (ReDataset, 2025).
Large (111–140 sqm)	Stable	High-spec luxury; price per sqm begins to stabilize (Elxis, 2025).

Extreme (>500 sqm)	Penalty/Discount	Sparse data; higher luxury asset illiquidity.

Table 23: Interpreting the Area Paradox in Market terms

6.5.2. Property floor level

The floor level factor was constantly addressed as an important factor for pricing in Agia Paraskevi. The findings are consistent across all models (Schulz et al., 2019) and confirm that height is rewarded in the area of Agia Paraskevi; natural lighting, reduced street noise and unobstructed view are rewarded as high-value attributes. Some decrease observed in the 8th floor properties may be explained considering roof top structures or other structures that cannot be compared to standard residencies appearing in the 6th, 7th floors (Lin & Chen, 2022).

This important of this factor is such that a high-floor property in a less respected neighborhood will often priced above a ground-floor apartment in a high-valued area (Lin & Chen, 2022; Matysiak, 2022). The results propose investments to consider properties above 2nd to maximize vertical premium.

6.5.3. Construction Year and Property condition

The relationship between the year of construction and property value was initially considered non-linear. Even if contemporary properties exhibit high values, which is also supported from the lack of newly built properties during crisis, chronological age is often not as important as is the "effective age" of a property, which derives maintenance, renovations, and upgrades (Winson-Geideman et al., 2008). This observation is exhibited from the interaction term between construction year and condition: renovation of older properties, provides additional market value which in practice "resets" the age of the property. In contrast to this observation, for very new properties, the interaction coefficient is often negative, acting as a slope correction. This example proposes renovation strategies for protecting capital in older buildings within Agia Paraskevi (Nikitidou et al., 2021).

Finally, the exclusion of temporal evolution in Agia Paraskevi market from 2021 to 2026, indicates a shift from growth to market maturation. The model results suggest that structural characteristics are more important than advertisement timing.

6.5.4. Energy Efficiency - Sustainability

The Greek Energy Performance Regulation for Buildings (KENAK) and Energy Performance Certificate (EPC) altered the property market by introducing sustainability as an important factor in pricing. The models present a market demand for high-efficiency buildings. As can be easily observed in the sensitivity section an apartment having an H EPC has almost 15% lower value than a residence having an A+ certificate. Given the European Union policies in Sustainability and the high energy costs this trend is expected to strengthen in the following years (BPIE, 2018).

6.5.5. Neighborhood Analysis

Neighborhood Analysis provides that the model is sensitive to the difference between the premium districts and outside areas like Pefkakia, where values are discounted almost 15%. This discount reflects Pefkakia’s position as a developing market in the area.

6.6. Sensitivity Analysis

To move beyond isolated coefficient interpretation, the study utilizes Global Sensitivity Analysis (GSA) to partition output variance among the predictors. This provides a clear "share of uncertainty" that reflects where market intervention or data quality improvement would be most effective (Saltelli et al., 2010).

The ANOVA results from Model 2D are presented in Table 17. The dominance of property area (86%) is an important point: measurement errors should be minimized to reduce prediction deviations. Furthermore, the fact that neighborhood (level4_geo) and energy class account for less than 1% each of the price variation suggests that Agia Paraskevi is a structurally homogeneous market where the physical utility of the asset (size and floor) is far more important than its precise micro-location or environmental rating. The results confirm the dominance of physical magnitude, with nearly 86% of the variance explained by size alone. Floor level is the only other factor to explain more than 5% of the variance, highlighting its unique role as a mandatory height premium (Lin & Chen, 2022). Notably, the model is more sensitive to a property's specific condition than to the chronological construction year itself, reinforcing the "effective age" thesis.

Furthermore a summary of the plotEffectss results is presented in the following Table 24, verifying and extending ANOVA analysis. The dominance of the area is evident while floor level follows in importance. Then is the condition of the property and energy class having moderate effects and in the end low effects are observed in the rest of the predictors.

Predictor	**Visual Magnitude (Approx.)**	**Direction**	**Reliability (confidence intervals' Width)**
Item_area (<500 sqm)	2.4	Positive	High (Very Tight)
Item_area (>580 sqm)	3.0	Negative	High (Very Tight)
Item_level	1.0 to 1.2	Positive	High (Tight)
Item_condition_specific	0.6 to 0.8	Positive	Moderate
Item_heating	0.1	Positive	Low (Very Tight)
Item_energy_class	0.1 to 0.2	Positive	Moderate
Item_heating_medium	0.1 to 0.3	Variable	Low (Wide CI)
Item_Construction_year	-0.2 to -0.3	Negative	Low (Tight)
Item_level4_geo	0.1	Positive	Low (Very Tight)

Table 24: Comparative Summary of Model Effects – Ploteffect results

In our research sensitivity analysis considered also AVP. Additional sensitivity analysis provided results appearing in **Error! Reference source not found.**, which summarizes the AVP sensitivity analysis and compares results from paragraphs 5.1, 5.2 and 5.3.

Variable	**Visual Trend & Significance**	**Interpretation / Meaning**
Item_level	Steep slope; distinct data clusters	High sensitivity; small changes in level drive large price shifts.
Item_area	Tight, slanted linear band; high confidence	A major, highly reliable driver of price despite the low per-unit slope.
Item_condition_specific	Steepest slope; mostly high-condition items	The most sensitive factor; condition changes impact price drastically.
Item_construction_year	Nearly flat; bounds contain zero slope	Not significant; age adds no unique value after other factors are considered.
Item_energy_class	Clear positive slant; uniform spread	Significant positive sensitivity; efficiency correlates with higher value.
Item_heating	Slight slant; wide data scatter	Low unique effect; heating type matters but is inconsistent in its impact.
Item_heating_medium	Shallow slope; very wide bounds	Marginally significant; one of the least influential unique predictors.
level4_geo	Moderate slant; bimodal distribution	Significant location influence, but secondary to physical attributes.

Table 25: Summary of Sensitivity Findings using APV interpretation

While the use of previous sensitivity tools is quite efficient for simple, linear models, plotPartialDependence provides additional information as model complexity increases. The superiority of plotPartialDependence becomes evident when stepwiselm includes non-linear terms. Thus, plotPartialDependence results exhibited low to zero sensitivity for the specific type of heating, heating medium, the construction year and the neighborhood, a secondary impact of the variable energy class and condition, the high sensitivity of the variable floor level. The important issue is the complete visualization of the non-linearity concerning area (Figure 22), depicting the three distinct areas of importance imposed by the variable.

As already discussed, the calculation of Sobol indices allows for the isolation of first-order effects from total-order effects, the latter of which includes all interactions with other variables. The interaction magnitude for "Item_condition_specific" (0.07) is significant, confirming that the impact of a property's condition is heavily dependent on its age and location. This observation supports the use of specific interaction terms in the regression models based on the market response and data and in the same time argues interpreting "renovation" considering the construction year of the property. Additionally, proposes exclusion of model parameters like heating medium, heating and neighborhood without compromising the model's overall predictive accuracy. Sobol indices verified property area as the most important predictor. However, in some cases like "Condition," the total-order index was higher than the first-order index, which signifies that the effect of the parameter is highly dependent on other factors like building age (Saltelli et al, 2010).

7. Conclusions and Recommendations

7.1. Summary of findings

The findings suggest that in the current period market exhibits structural maturity characteristics (Astons Greece, 2026). In this vein, the dominant drivers of the market are specific - not all of the - physical and structural characteristics rather than timing of the transaction. Computational stability of the prevalent Model 2D across only 6,900 observations proves that the Agia Paraskevi market operates under balanced, evident laws. The "Area Paradox" and the "Verticality Premium" are the two of the major drivers of this market: while larger apartments face lower unit prices due to non-linearities of the models, the market strongly rewards height, especially over 2nd floor valuating almost exponentially light, air and view (Matysiak, 2022). Furthermore, the exclusion of time posting variable from the final results confirms that properties in Agia Paraskevi are valued independent of transaction time.

7.2. Market Synthesis and Interpretation of Consolidated Predictors

The relationship between Area and Transaction price, as shown in Model 2D, demonstrates the law of diminishing marginal returns. The positive linear term and negative quadratic term creates three distinct cases: a. an almost linear price increase with the area until 450 sqm, b. the peak between 450 and 550 square meters and steep decrease for areas greater than 550 sqm. The "Area Paradox" suggests that smaller, and mid-sized residencies are more valuated than larger properties.

The floor level is also a dominant factor. Increasing floor level leads to constantly increased prices. The limited drop observed at the 8th-floor level suggests that these units may be smaller penthouse setbacks (δώματα) having less amenities compared to full-floor apartments on the lower levels.

Chronological age and effective age are distinctive in the above discussed research. Even if newer properties have a greater price, the negative interaction term between construction year and property condition acts as a slope correction reducing collinearities or double-counting newly built and excellent condition valuating. Interaction provide also that strategic renovations for older buildings can reset their age in the sense of capturing competitive values compared to newer constructions.

Finally, energy efficiency based on EPC's is also a secondary factor to the price. Low-efficiency properties (Class H) are discounted approximately 15% relative to the A+ baseline. This is a result of energy poverty and increase both property and environmental risks. However, the increased cost of newly built housing has created an "affordability paradox," where buyers are driven toward cheaper, older, less efficient secondary market properties.

7.3. Conclusions

Based on the above analysis of the Agia Paraskevi residential market, the following conclusions are derived:

- The dominance of property area over all other factors is absolute, explaining nearly 86% of price variance. This relationship is non-linear and governed by diminishing marginal returns. Smaller units (20-110 sqm) drive the highest price-per-square-meter growth, while units exceeding 550 sqm face a market "penalty".
- Floor level is a "hard" driver of value, with consistent price increase. The peak occurs at the 7th floor, representing quality of air, view and noise mitigation across all neighborhoods.
- The market prioritizes "Effective Age" over "Chronological Age." Non linearities present that strategic renovations for older buildings can reset their age in the sense of capturing competitive values compared to newer constructions.
- The "Green Premium" and "Affordability Paradox" exist in a state of tension. While efficiency is rewarded, high cost of newly built houses promotes cheaper, less efficient properties. Then the quality benchmark of the energy efficiency is achieved through cheaper options like renovating older stock.
- Model 2D configuration represents the optimal choice for mass appraisal applications combined with limited data. Efficiency having models with increased complexity demands extreme data density and appropriate quality and quantity of data, increasing model complexity leads to overfitting and numerical instability.

7.4. Recommendations

The consolidated findings of this research provide a clear framework for decision-making across the real estate sector in northern Athens.

7.4.1. Recommendations for Real Estate Investors and Developers

- **Invest in Small and Mid-Sized Units:** The "Area Paradox" states that high price-per-square-meter values are related to residential properties under 110 square meters. Developers should design and construct small-to-medium units to maximize profits and avoid reduced prices observed with larger assets.
- **Renovate the Older Stock:** Investors can generate significant profit by renovating pre-1990 properties which can be bought by discount. Combining renovation with energy efficiency and sustainability update resets their effective age, allowing their values to be comparable to newer constructions.
- **Select Higher Floors:** Verticality and height is a highly valued and stable premium in Athens. Development and acquisition strategies should focus on higher floor levels starting from the 3rd floor and above to capture light, air and view.

7.4.2. Recommendations for Financial Institutions and Risk Managers

- **Implement Model 2D Configuration:** The configuration of the Model 2D can be used for real estate pricing models. It offers computational stability and an effective MAPE of 13.92%.
- **Exploit the Area Paradox:** Risk models must consider quadratic terms for property area to avoid overvaluation of properties larger than 400 sqm and the undervaluation of compact and mid-sized units.
- **Manage low-efficiency properties:** Focus should be given from portfolio managers to the minimization of low-efficiency properties (Class F-H). Given that environmental regulations become stricter, prices are declining residencies are depreciated and financial risks concerning loan-to-value appear in the market.

7.4.3. Recommendations for Policy Makers and Urban Planners

- **Introduce and increase residential Energy Upgrade programs:** To address the "affordability paradox," and extremely high prices of newly built residencies, government should increase funding and subsidies for energy-efficient upgrades. Focus should be given to lower-income households to reduce energy poverty.

- **Streamline Legal Frameworks for Regeneration:** Building renovation procedures should be simplified to encourage owners to reuse existing stock and also decrease the environmental impact of new construction and enhance sustainability.
- **Improve Local Transportation:** To reduce the spatial effect observed in peripheral districts like Pefkakia, connectivity of the local to metropolitan transfer options should be redesigned. Improving localized connectivity reduce price differences and supports growth.

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Appendix A: Stepwiselm results for 2A-2E, 1B, 1D, 1E, 3B, 3D, 3E

Author's Statement:

I hereby expressly declare that, according to the article 8 of **Law 1559/1986**, this dissertation is solely the product of my personal work, does not infringe any intellectual property, personality and personal data rights of third parties, does not contain works/contributions from third parties for which the permission of the authors/beneficiaries is required, is not the product of partial or total plagiarism, and that the sources used are limited to the literature references alone and meet the rules of scientific citations.

mdlinter1B =

Linear regression model:

    Transaction_price ~ [Linear formula with 12 terms in 8 predictors]

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	11.501	0.26661	43.137	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.097123	0.019095	-5.0863	3.8089e-07
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.16116	0.0318	-5.0681	4.1896e-07
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.014562	0.014343	-1.0153	0.31004
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.12451	0.011795	-10.556	9.8793e-26
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.068283	0.015715	-4.3451	1.4244e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.11978	0.014372	-8.3341	1.0424e-16
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.15524	0.019615	-7.9144	3.1452e-15
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.05376	0.014623	-3.6764	0.00023945
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	-0.021855	0.012886	-1.696	0.089958
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.10373	0.017726	-5.8519	5.2262e-09
Item_area	0.0056422	7.0378e-05	80.171	0
Item_construction_year	-0.0045611	0.0042642	-1.0696	0.28484
Item_level_ΗΜΙΥΠ	0.18002	0.080576	2.2341	0.025525
Item_level_ΙΣ	0.77883	0.072886	10.686	2.5581e-26
Item_level_ΥΠΙΣ	0.793	0.076874	10.316	1.1672e-24
Item_level_ΗΜ	0.9492	0.10822	8.7709	2.5212e-18
Item_level_1Ο	0.88638	0.072377	12.247	6.4782e-34
Item_level_2Ο	0.93107	0.072565	12.831	5.3055e-37
Item_level_3Ο	0.9943	0.072584	13.699	7.8948e-42
Item_level_4Ο	1.0292	0.072517	14.192	1.0536e-44

Item_level_5O	1.0875	0.073386	14.819	1.748e-48
Item_level_6O	1.1736	0.076094	15.423	2.8957e-52
Item_level_8O	1.1439	0.10373	11.028	6.6796e-28
Item_energy_class_A	-0.04446	0.014428	-3.0816	0.0020723
Item_energy_class_B+	-0.062294	0.031067	-2.0052	0.045009
Item_energy_class_B	-0.082493	0.021251	-3.8819	0.00010521
Item_energy_class_Γ	-0.12354	0.021117	-5.8505	5.268e-09
Item_energy_class_Δ	-0.12461	0.020903	-5.9614	2.7035e-09
Item_energy_class_E	-0.14959	0.022416	-6.6734	2.8211e-11
Item_energy_class_Z	-0.13496	0.024834	-5.4344	5.8074e-08
Item_energy_class_H	-0.19313	0.025558	-7.5565	5.0394e-14
Item_condition_specific_υπό κατασκευή	0.16741	0.25929	0.64566	0.51853
Item_condition_specific_χρήζει ανακαίνισης	-0.1293	0.26221	-0.49313	0.62195
Item_condition_specific_καλή κατάσταση	-0.30727	0.25256	-1.2166	0.22382
Item_condition_specific_ανακαινισμένο	-0.26062	0.25412	-1.0256	0.30515
Item_condition_specific_νεόδμητο	0.16224	0.27472	0.59054	0.55486
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0063776	0.0078773	0.80962	0.4182
Item_heating_κεντρική θέρμανση	-0.097313	0.014116	-6.894	6.2248e-12
Item_heating_χωρίς θέρμανση	-0.065219	0.093039	-0.70099	0.48335
Item_heating_medium_πετρέλαιο	-0.0060702	0.010242	-0.59267	0.55343
Item_heating_medium_ρεύμα	-0.034425	0.010079	-3.4157	0.00064225
Item_heating_medium_pellet	0.41151	0.22766	1.8076	0.070746
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.0033349	0.0038034	-0.87682	0.38063
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.0071827	0.0045285	-1.5861	0.11279
Item_construction_year:Item_condition_specific_καλή κατάσταση	0.0031348	0.003733	0.83975	0.4011
Item_construction_year:Item_condition_specific_ανακαινισμένο	0.0023134	0.0038288	0.60419	0.54575
Item_construction_year:Item_condition_specific_νεόδμητο	-0.0034427	0.0040157	-0.8573	0.39133
Item_area^2	-6.8735e-07	9.2787e-09	-74.078	0
Item_construction_year^2	8.0569e-05	2.1909e-05	3.6774	0.00023849

Number of observations: 4303, Error degrees of freedom: 4253

```
Root Mean Squared Error: 0.225
R-squared: 0.784,  Adjusted R-Squared: 0.782
F-statistic vs. constant model: 315, p-value = 0

computmape =

   20.0925

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.508278e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Binter (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  3.389628e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Binter (line 38)


ans =

  12×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	10.341	10	1.0341	20.367	2.4558e-37
Item_area	47.805	1	47.805	941.5	5.9554e-187
Item_construction_year	6.5779	1	6.5779	129.55	1.3737e-29
Item_level	59.699	11	5.4272	106.89	7.1504e-216

Item_energy_class	3.4454	8	0.43067	8.4818	1.6403e-11
Item_condition_specific	2.1626	5	0.43252	8.5183	4.901e-08
Item_heating	3.2543	3	1.0848	21.364	9.8907e-14
Item_heating_medium	0.76908	3	0.25636	5.0489	0.0017157
Item_construction_year:Item_condition_specific	4.1617	5	0.83234	16.393	4.6809e-16
Item_area^2	278.63	1	278.63	5487.6	0
Item_construction_year^2	0.68667	1	0.68667	13.524	0.00023849
Error	215.95	4253	0.050776		

```
mdlinter1D = 


Linear regression model:
    Transaction_price ~ [Linear formula with 13 terms in 9 predictors]

Estimated Coefficients:
                                                     Estimate        SE         tStat       pValue   
                                                    __________    _________    ________    __________

    (Intercept)                                         11.302      0.25877      43.675             0
    time                                             0.0037191    0.0016764      2.2185      0.026577
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων         -0.084384      0.01856     -4.5466    5.6111e-06
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ                      -0.1674     0.031313     -5.3459    9.4951e-08
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου               -0.0081009     0.013885    -0.58343       0.55963
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο              -0.11847      0.01164     -10.177    4.8783e-24
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή                -0.067196     0.015389     -4.3664    1.2949e-05
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος              -0.12266     0.014126      -8.683    5.5097e-18
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια                -0.13851     0.019229     -7.2034    6.9737e-13
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας         -0.051781     0.014047     -3.6862    0.00023065
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός                -0.024304     0.012745     -1.9069      0.056607
    level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός                 -0.094621     0.017314      -5.465    4.9081e-08
    Item_area                                        0.0060619   7.1495e-05      84.788             0
    Item_construction_year                          -0.0042446    0.0041705     -1.0178       0.30885
    Item_level_ΗΜΙΥΠ                                   0.28363     0.080475      3.5245    0.00042902
    Item_level_ΙΣ                                      0.86273     0.073548       11.73    2.8571e-31
    Item_level_ΥΠΙΣ                                    0.87466      0.07707      11.349    2.0877e-29
    Item_level_ΗΜ                                       1.0359      0.10606      9.7671     2.747e-22
    Item_level_1Ο                                      0.96939     0.073028      13.274    2.1655e-39
    Item_level_2Ο                                       1.0106     0.073208      13.804    2.1733e-42
    Item_level_3Ο                                       1.0748     0.073237      14.675    1.5313e-47
```

Item_level_4O	1.108	0.07316	15.145	1.9465e-50
Item_level_5O	1.1554	0.074019	15.61	2.2041e-53
Item_level_6O	1.2348	0.076878	16.062	2.5454e-56
Item_level_8O	1.2169	0.10744	11.326	2.6913e-29
Item_energy_class_A	-0.028126	0.014178	-1.9838	0.047345
Item_energy_class_B+	-0.053267	0.03086	-1.7261	0.084401
Item_energy_class_B	-0.083957	0.021076	-3.9835	6.9098e-05
Item_energy_class_Γ	-0.12125	0.020936	-5.7917	7.5001e-09
Item_energy_class_Δ	-0.12281	0.020841	-5.8926	4.1125e-09
Item_energy_class_E	-0.14822	0.022206	-6.6745	2.8177e-11
Item_energy_class_Z	-0.13123	0.024505	-5.3554	9.014e-08
Item_energy_class_H	-0.19103	0.025078	-7.6174	3.2048e-14
Item_condition_specific_υπό κατασκευή	0.196	0.24915	0.7867	0.4315
Item_condition_specific_χρήζει ανακαίνισης	-0.13037	0.25155	-0.51827	0.6043
Item_condition_specific_καλή κατάσταση	-0.30965	0.24228	-1.2781	0.2013
Item_condition_specific_ανακαινισμένο	-0.23532	0.24388	-0.96491	0.33465
Item_condition_specific_νεόδμητο	0.17005	0.2637	0.64487	0.51905
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0076905	0.0077169	0.99658	0.31903
Item_heating_κεντρική θέρμανση	-0.098608	0.013781	-7.1552	9.8739e-13
Item_heating_χωρίς θέρμανση	-0.061115	0.088961	-0.68698	0.49213
Item_heating_medium_πετρέλαιο	-0.010167	0.0099742	-1.0194	0.30809
Item_heating_medium_ρεύμα	-0.034502	0.010011	-3.4462	0.00057426
Item_heating_medium_pellet	0.36637	0.21757	1.6839	0.092274
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.0037145	0.0037274	-0.99654	0.31905
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.0074046	0.00441	-1.679	0.093223
Item_construction_year:Item_condition_specific_καλή κατάσταση	0.0029801	0.0036568	0.81495	0.41515
Item_construction_year:Item_condition_specific_ανακαινισμένο	0.0014044	0.0037502	0.37448	0.70807
Item_construction_year:Item_condition_specific_νεόδμητο	-0.0036048	0.0039246	-0.9185	0.35841
Item_area^2	-7.3762e-07	9.3376e-09	-78.995	0
Item_construction_year^2	7.7531e-05	2.1394e-05	3.624	0.00029367

```
Number of observations: 4086, Error degrees of freedom: 4035
Root Mean Squared Error: 0.215
R-squared: 0.804,  Adjusted R-Squared: 0.801
F-statistic vs. constant model: 330, p-value = 0

computmape =

   19.2571

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.446107e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Dinter (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  3.358926e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Dinter (line 38)


ans =

  13×5 table
```

	SumSq	DF	MeanSq	F	pValue
time	0.22814	1	0.22814	4.9217	0.026577
level4_geo	9.0406	10	0.90406	19.503	1.4315e-35
Item_area	44.063	1	44.063	950.56	1.2865e-187

Item_construction_year	5.3412	1	5.3412	115.22	1.598e-26
Item_level	53.983	11	4.9076	105.87	1.1487e-212
Item_energy_class	3.1747	8	0.39684	8.5608	1.2491e-11
Item_condition_specific	2.4743	5	0.49486	10.676	3.2887e-10
Item_heating	3.2678	3	1.0893	23.499	4.4935e-15
Item_heating_medium	0.70512	3	0.23504	5.0704	0.0016656
Item_construction_year:Item_condition_specific	4.1271	5	0.82542	17.807	1.6859e-17
Item_area^2	289.26	1	289.26	6240.2	0
Item_construction_year^2	0.60879	1	0.60879	13.133	0.00029367
Error	187.04	4035	0.046355		

mdlinter1E =

Linear regression model:
    Transaction_price ~ [Linear formula with 14 terms in 9 predictors]

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	11.28	0.26838	42.03	0
time	0.023199	0.0096587	2.4019	0.016348
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.10447	0.017733	-5.8914	4.0958e-09
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.15028	0.030316	-4.9569	7.4129e-07
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.0096106	0.013247	-0.72548	0.46819
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.12282	0.011073	-11.092	3.0495e-28
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.064015	0.014811	-4.322	1.5778e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.12531	0.013503	-9.2805	2.5078e-20
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.15999	0.018166	-8.8069	1.7775e-18
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.054063	0.013642	-3.9629	7.5146e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	-0.02012	0.012091	-1.6641	0.096167
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.10041	0.016591	-6.0519	1.5423e-09
Item_area	0.0057184	6.6092e-05	86.522	0
Item_construction_year	-0.0041537	0.0040909	-1.0153	0.31
Item_level_ΗΜΙΥΠ	0.21756	0.07553	2.8805	0.0039887
Item_level_ΙΣ	0.79553	0.068138	11.675	4.5309e-31
Item_level_ΥΠΙΣ	0.81802	0.07191	11.376	1.3375e-29
Item_level_ΗΜ	0.96219	0.10388	9.2626	2.9566e-20
Item_level_1Ο	0.89744	0.067673	13.261	1.9505e-39
Item_level_2Ο	0.94558	0.067847	13.937	2.6947e-43
Item_level_3Ο	1.0043	0.067863	14.798	1.8008e-48
Item_level_4Ο	1.0441	0.067808	15.398	3.0939e-52

Item_level_5O	1.0977	0.068589	16.005	3.4787e-56
Item_level_6O	1.1844	0.071109	16.657	1.4046e-60
Item_level_8O	1.1476	0.099259	11.561	1.6558e-30
Item_energy_class_A	-0.046853	0.013486	-3.4742	0.00051701
Item_energy_class_B+	-0.081136	0.027398	-2.9614	0.0030774
Item_energy_class_B	-0.097465	0.018995	-5.1312	2.9945e-07
Item_energy_class_Γ	-0.12834	0.019046	-6.7386	1.7902e-11
Item_energy_class_Δ	-0.13086	0.018819	-6.9535	4.0481e-12
Item_energy_class_E	-0.14737	0.020333	-7.2476	4.929e-13
Item_energy_class_Z	-0.13778	0.022809	-6.0408	1.6508e-09
Item_energy_class_H	-0.19059	0.023057	-8.266	1.7824e-16
Item_condition_specific_υπό κατασκευή	0.17782	0.25381	0.70062	0.48358
Item_condition_specific_χρήζει ανακαίνισης	-0.13277	0.25609	-0.51845	0.60417
Item_condition_specific_καλή κατάσταση	-0.3106	0.24726	-1.2562	0.20912
Item_condition_specific_ανακαινισμένο	-0.26234	0.24864	-1.0551	0.29143
Item_condition_specific_νεόδμητο	0.18109	0.26666	0.67911	0.4971
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0055811	0.00732	0.76245	0.44583
Item_heating_κεντρική θέρμανση	-0.097063	0.013189	-7.3595	2.1653e-13
Item_heating_χωρίς θέρμανση	-0.064784	0.0911	-0.71113	0.47704
Item_heating_medium_πετρέλαιο	-0.0059022	0.0095292	-0.61939	0.53569
Item_heating_medium_ρεύμα	-0.034696	0.0094777	-3.6608	0.00025421
Item_heating_medium_pellet	0.39081	0.22294	1.7529	0.079676
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.0034697	0.0037002	-0.93768	0.34846
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.0070316	0.0043554	-1.6145	0.1065
Item_construction_year:Item_condition_specific_καλή κατάσταση	0.0032711	0.0036298	0.90116	0.36755
Item_construction_year:Item_condition_specific_ανακαινισμένο	0.0024563	0.0037111	0.66188	0.50808
Item_construction_year:Item_condition_specific_νεόδμητο	-0.0036896	0.0038791	-0.95114	0.34158
time^2	-0.00068956	0.00033671	-2.0479	0.040622
Item_area^2	-6.9654e-07	8.775e-09	-79.377	0
Item_construction_year^2	7.6314e-05	2.0034e-05	3.8092	0.00014119

```
Number of observations: 4778, Error degrees of freedom: 4726
Root Mean Squared Error: 0.221
R-squared: 0.791,  Adjusted R-Squared: 0.789
F-statistic vs. constant model: 350, p-value = 0

computmape =

   19.7503

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.521627e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Einter (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  3.413945e-17.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens51Einter (line 38)


ans =

  14×5 table
```

	SumSq	DF	MeanSq	F	pValue
time	0.2577	1	0.2577	5.2817	0.021595
level4_geo	11.703	10	1.1703	23.985	1.1516e-44
Item_area	57.971	1	57.971	1188.1	1.8335e-232

Item_construction_year	8.2643	1	8.2643	169.38	4.5327e-38
Item_level	63.442	11	5.7675	118.21	1.1124e-239
Item_energy_class	3.749	8	0.46862	9.6045	2.7494e-13
Item_condition_specific	2.2732	5	0.45463	9.3178	7.616e-09
Item_heating	3.5153	3	1.1718	24.016	2.0254e-15
Item_heating_medium	0.81453	3	0.27151	5.5647	0.00082767
Item_construction_year:Item_condition_specific	4.7368	5	0.94736	19.416	3.4559e-19
time^2	0.20463	1	0.20463	4.194	0.040622
Item_area^2	307.42	1	307.42	6300.7	0
Item_construction_year^2	0.70797	1	0.70797	14.51	0.00014119
Error	230.59	4726	0.048792		

mdlinter2A =

Linear regression model:
    Transaction_price ~ [Linear formula with 11 terms in 7 predictors]

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	10.552	0.18239	57.852	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.026757	0.022366	-1.1963	0.23167
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.068605	0.034666	-1.979	0.047913
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.014512	0.016366	-0.88673	0.3753
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.058241	0.013983	-4.1652	3.2039e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.017041	0.019397	-0.87855	0.37972
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.042896	0.015561	-2.7566	0.0058773
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.15703	0.021351	-7.3547	2.4958e-13
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.031742	0.016664	-1.9048	0.056911
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	-0.016874	0.016652	-1.0133	0.31101
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.061787	0.021609	-2.8593	0.0042769
Item_area	0.0092842	0.00015638	59.37	0
Item_construction_year	-0.0099097	0.0033541	-2.9545	0.0031579
Item_level_ΗΜΥΠ	0.18576	0.080997	2.2935	0.021894
Item_level_ΙΣ	0.65379	0.071402	9.1565	1.0031e-19
Item_level_ΥΠΙΣ	0.64574	0.075725	8.5275	2.4019e-17
Item_level_ΗΜ	0.73856	0.11423	6.4653	1.1876e-10
Item_level_1Ο	0.72566	0.070433	10.303	1.8495e-24
Item_level_2Ο	0.74564	0.070877	10.52	2.052e-25
Item_level_3Ο	0.81498	0.071208	11.445	1.1141e-29
Item_level_4Ο	0.88822	0.071476	12.427	1.4771e-34
Item_level_5Ο	0.86352	0.073497	11.749	3.7639e-31

Item_level_6O	0.95699	0.080016	11.96	3.4168e-32
Item_level_8O	0.93032	0.098297	9.4644	6.0215e-21
Item_energy_class_A	-0.026268	0.018424	-1.4257	0.15405
Item_energy_class_B+	-0.0048226	0.035732	-0.13496	0.89265
Item_energy_class_B	-0.028433	0.026611	-1.0685	0.2854
Item_energy_class_Γ	-0.072929	0.025926	-2.813	0.0049425
Item_energy_class_Δ	-0.088506	0.025659	-3.4493	0.00057024
Item_energy_class_E	-0.10819	0.025627	-4.2218	2.5008e-05
Item_energy_class_Z	-0.1037	0.028915	-3.5863	0.00034108
Item_energy_class_H	-0.11774	0.024673	-4.7719	1.9181e-06
Item_condition_specific_υπό κατασκευή	1.2181	0.17895	6.8067	1.2155e-11
Item_condition_specific_χρήζει ανακαίνισης	0.73121	0.17027	4.2943	1.8114e-05
Item_condition_specific_καλή κατάσταση	0.64417	0.15963	4.0353	5.5978e-05
Item_condition_specific_ανακαινισμένο	0.6907	0.16297	4.2382	2.3255e-05
Item_condition_specific_νεόδμητο	0.70741	0.2179	3.2465	0.0011818
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.017931	0.0099018	1.8108	0.070271
Item_heating_κεντρική θέρμανση	-0.096989	0.015506	-6.255	4.5791e-10
Item_heating_χωρίς θέρμανση	-0.07123	0.016539	-4.3068	1.7128e-05
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.011145	0.0029162	-3.8217	0.00013543
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.010701	0.003524	-3.0365	0.0024152
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.0027403	0.0027265	-1.0051	0.31494
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.0028353	0.0028688	-0.98833	0.32308
Item_construction_year:Item_condition_specific_νεόδμητο	-0.0042246	0.0034357	-1.2296	0.21895
Item_area^2	-8.6352e-06	2.9335e-07	-29.436	2.7039e-166
Item_construction_year^2	0.00020635	2.168e-05	9.518	3.6592e-21

Number of observations: 2865, Error degrees of freedom: 2818
Root Mean Squared Error: 0.218
R-squared: 0.802, Adjusted R-Squared: 0.799
F-statistic vs. constant model: 248, p-value = 0

```
computmape =

   15.5594


ans =

  11×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	3.2283	10	0.32283	6.7813	1.6007e-10
Item_area	287.07	1	287.07	6030	0
Item_construction_year	2.6499	1	2.6499	55.663	1.1391e-13
Item_level	26.957	11	2.4506	51.476	8.3987e-104
Item_energy_class	1.933	8	0.24163	5.0756	2.7479e-06
Item_condition_specific	10.856	5	2.1713	45.609	1.9937e-45
Item_heating	3.7549	3	1.2516	26.291	9.0796e-17
Item_construction_year:Item_condition_specific	2.9945	5	0.5989	12.58	4.1788e-12
Item_area^2	41.251	1	41.251	866.49	2.7039e-166
Item_construction_year^2	4.3128	1	4.3128	90.592	3.6592e-21
Error	134.16	2818	0.04760		

```
mdlinter2B =


Linear regression model:
    Transaction_price ~ [Linear formula with 12 terms in 8 predictors]

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	9.8565	0.11687	84.34	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.054449	0.013462	-4.0447	5.292e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.019804	0.018959	-1.0446	0.29625
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.016612	0.0099116	-1.676	0.093783
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.055274	0.007888	-7.0073	2.6453e-12
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.024833	0.010823	-2.2946	0.021785
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.045146	0.0091969	-4.9088	9.3623e-07
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.13507	0.01231	-10.973	8.5129e-28
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.035115	0.010182	-3.4488	0.00056617
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	-0.00073025	0.0088004	-0.082979	0.93387
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.042221	0.012986	-3.2513	0.0011538
Item_area	0.0090076	7.4728e-05	120.54	0
Item_construction_year	0.0048684	0.0020561	2.3678	0.017921
Item_level_ΗΜΙΥΠ	0.15957	0.052191	3.0574	0.0022404
Item_level_ΙΣ	0.68168	0.046178	14.762	1.2808e-48
Item_level_ΥΠΙΣ	0.65611	0.048841	13.434	1.1647e-40
Item_level_ΗΜ	0.78189	0.071017	11.01	5.668e-28
Item_level_1Ο	0.75225	0.045837	16.411	1.8174e-59
Item_level_2Ο	0.77917	0.045996	16.94	3.6218e-63
Item_level_3Ο	0.84723	0.046051	18.398	6.2691e-74
Item_level_4Ο	0.90155	0.046054	19.576	3.2596e-83
Item_level_5Ο	0.91737	0.046586	19.692	3.7396e-84

Item_level_6O	0.95621	0.048015	19.915	5.5607e-86
Item_level_7O	1.0181	0.14993	6.7905	1.2053e-11
Item_level_8O	0.93424	0.061219	15.261	8.7264e-52
Item_energy_class_A	-0.037425	0.0096092	-3.8946	9.9218e-05
Item_energy_class_B+	-0.068445	0.02479	-2.761	0.0057762
Item_energy_class_B	-0.081747	0.01562	-5.2336	1.7089e-07
Item_energy_class_Γ	-0.11257	0.015304	-7.3552	2.1133e-13
Item_energy_class_Δ	-0.12037	0.015236	-7.8999	3.1989e-15
Item_energy_class_E	-0.16822	0.01562	-10.769	7.6383e-27
Item_energy_class_Z	-0.15239	0.018229	-8.3599	7.4439e-17
Item_energy_class_H	-0.16665	0.014887	-11.194	7.4498e-29
Item_condition_specific_υπό κατασκευή	1.8368	0.11301	16.253	2.2132e-58
Item_condition_specific_χρήζει ανακαίνισης	1.5163	0.11049	13.724	2.4361e-42
Item_condition_specific_καλή κατάσταση	1.3588	0.10113	13.435	1.1368e-40
Item_condition_specific_ανακαινισμένο	1.3849	0.10376	13.347	3.6221e-40
Item_condition_specific_νεόδμητο	1.5778	0.13052	12.088	2.5316e-33
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0089575	0.0055207	1.6225	0.10473
Item_heating_κεντρική θέρμανση	-0.089674	0.010136	-8.8467	1.1154e-18
Item_heating_χωρίς θέρμανση	-0.049204	0.012584	-3.9101	9.3092e-05
Item_heating_medium_πετρέλαιο	-0.010937	0.007341	-1.4898	0.13632
Item_heating_medium_ρεύμα	-0.030686	0.0075376	-4.0711	4.7294e-05
Item_heating_medium_pellet	-0.044122	0.11768	-0.37492	0.70773
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.022116	0.0017076	-12.951	6.0114e-38
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.025888	0.0022621	-11.444	4.544e-30
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.015409	0.0015825	-9.7372	2.8557e-22
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.015169	0.001702	-8.9125	6.2118e-19
Item_construction_year:Item_condition_specific_νεόδμητο	-0.018767	0.0019499	-9.6246	8.4718e-22
Item_area^2	-7.7592e-06	1.1174e-07	-69.437	0
Item_construction_year^2	0.00017285	1.3882e-05	12.451	3.1403e-35

Number of observations: 7363, Error degrees of freedom: 7312

```
Root Mean Squared Error: 0.202
R-squared: 0.837,  Adjusted R-Squared: 0.836
F-statistic vs. constant model: 750, p-value = 0

computmape =

   14.2269


ans =

  12×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	6.6512	10	0.66512	16.344	1.4269e-29
Item_area	550.41	1	550.41	13525	0
Item_construction_year	6.2798	1	6.2798	154.31	4.4664e-35
Item_level	75.584	12	6.2987	154.77	0
Item_energy_class	6.6394	8	0.82992	20.393	8.0793e-31
Item_condition_specific	18.007	5	3.6014	88.495	1.1788e-90
Item_heating	4.8707	3	1.6236	39.895	1.4529e-25
Item_heating_medium	0.71479	3	0.23826	5.8547	0.00054605
Item_construction_year:Item_condition_specific	9.741	5	1.9482	47.872	6.827e-49
Item_area^2	196.21	1	196.21	4821.4	0
Item_construction_year^2	6.3089	1	6.3089	155.03	3.1403e-35
Error	297.57	7312	0.040696		

```
mdlinter2C =


Linear regression model:
    Transaction_price ~ [Linear formula with 12 terms in 8 predictors]

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	10.08	0.13164	76.576	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.049137	0.016021	-3.0671	0.0021727
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.039519	0.02429	-1.627	0.1038
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.0057208	0.011964	-0.47817	0.63255
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.059992	0.0097068	-6.1804	6.872e-10
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.027416	0.013266	-2.0666	0.038821
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.037727	0.011334	-3.3288	0.00087827
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.13384	0.014894	-8.986	3.5014e-19
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.026459	0.012256	-2.1588	0.030908
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	0.0028746	0.01074	0.26767	0.78897
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.039853	0.01606	-2.4816	0.013111
Item_area	0.0089276	8.6754e-05	102.91	0
Item_construction_year	0.0012928	0.0023518	0.54969	0.58256
Item_level_ΗΜΥΠ	0.13799	0.06115	2.2567	0.024069
Item_level_ΙΣ	0.69999	0.054204	12.914	1.3778e-37
Item_level_ΥΠΙΣ	0.66923	0.057773	11.584	1.1607e-30
Item_level_ΗΜ	0.80415	0.078286	10.272	1.5987e-24
Item_level_1Ο	0.7695	0.053811	14.3	1.5257e-45
Item_level_2Ο	0.79098	0.054048	14.635	1.4118e-47
Item_level_3Ο	0.86326	0.054159	15.939	6.615e-56
Item_level_4Ο	0.91537	0.054238	16.877	2.7471e-62
Item_level_5Ο	0.9299	0.054872	16.947	8.9101e-63

Item_level_6O	0.96556	0.056678	17.036	2.1155e-63
Item_level_7O	1.0331	0.159	6.4974	8.9197e-11
Item_level_8O	0.933	0.072892	12.8	5.7725e-37
Item_energy_class_A	-0.040736	0.011737	-3.4709	0.00052287
Item_energy_class_B+	-0.060985	0.028723	-2.1232	0.033782
Item_energy_class_B	-0.069685	0.020004	-3.4836	0.00049871
Item_energy_class_Γ	-0.11629	0.019361	-6.0063	2.0245e-09
Item_energy_class_Δ	-0.1302	0.019257	-6.7614	1.5137e-11
Item_energy_class_E	-0.1679	0.019447	-8.6337	7.754e-18
Item_energy_class_Z	-0.13846	0.022378	-6.1872	6.5846e-10
Item_energy_class_H	-0.16804	0.018707	-8.9824	3.6158e-19
Item_condition_specific_υπό κατασκευή	1.6303	0.12928	12.611	6.0007e-36
Item_condition_specific_χρήζει ανακαίνισης	1.2949	0.12307	10.521	1.2292e-25
Item_condition_specific_καλή κατάσταση	1.1281	0.11233	10.043	1.6004e-23
Item_condition_specific_ανακαινισμένο	1.1305	0.11553	9.7849	2.0208e-22
Item_condition_specific_νεόδμητο	1.3807	0.14314	9.6458	7.735e-22
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.010592	0.0068241	1.5522	0.12068
Item_heating_κεντρική θέρμανση	-0.089131	0.012178	-7.3192	2.8678e-13
Item_heating_χωρίς θέρμανση	-0.04885	0.015431	-3.1657	0.001556
Item_heating_medium_πετρέλαιο	-0.012668	0.0090071	-1.4064	0.15965
Item_heating_medium_ρεύμα	-0.033529	0.0096195	-3.4855	0.0004952
Item_heating_medium_pellet	-0.026481	0.1238	-0.2139	0.83064
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.019569	0.001952	-10.025	1.9144e-23
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.023553	0.0025752	-9.1461	8.2465e-20
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.012524	0.0017705	-7.0735	1.7067e-12
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.011676	0.0019174	-6.0894	1.2132e-09
Item_construction_year:Item_condition_specific_νεόδμητο	-0.016395	0.0021538	-7.6121	3.1733e-14
Item_area^2	-7.5789e-06	1.231e-07	-61.568	0
Item_construction_year^2	0.00018192	1.6728e-05	10.875	2.9345e-27

Number of observations: 5354, Error degrees of freedom: 5303

```
Root Mean Squared Error: 0.211
R-squared: 0.834,  Adjusted R-Squared: 0.832
F-statistic vs. constant model: 531, p-value = 0

computmape =

   14.9509


ans =

  12×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	5.3235	10	0.53235	11.919	1.3127e-20
Item_area	412.5	1	412.5	9235.7	0
Item_construction_year	4.2036	1	4.2036	94.116	4.5346e-22
Item_level	57.437	12	4.7864	107.16	2.9562e-239
Item_energy_class	5.0425	8	0.63031	14.112	1.6418e-20
Item_condition_specific	11.701	5	2.3403	52.397	3.1425e-53
Item_heating	3.772	3	1.2573	28.151	4.7086e-18
Item_heating_medium	0.58488	3	0.19496	4.3651	0.0044661
Item_construction_year:Item_condition_specific	7.1841	5	1.4368	32.169	2.0654e-32
Item_area^2	169.3	1	169.3	3790.6	0
Item_construction_year^2	5.2823	1	5.2823	118.27	2.9345e-27
Error	236.85	5303	0.044664		

```
mdlinter2D =


Linear regression model:
    Transaction_price ~ [Linear formula with 12 terms in 8 predictors]

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	9.9697	0.11771	84.694	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.050913	0.013691	-3.7186	0.00020193
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.020005	0.019743	-1.0133	0.31097
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.012084	0.010084	-1.1983	0.23084
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.046763	0.0081413	-5.7439	9.6508e-09
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.021146	0.01114	-1.8981	0.057725
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.041068	0.0094589	-4.3418	1.4338e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.1263	0.012655	-9.9799	2.6897e-23
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.033328	0.010332	-3.2258	0.0012619
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	0.00062067	0.0091069	0.068154	0.94566
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.032363	0.013256	-2.4414	0.014656
Item_area	0.010036	0.00010293	97.505	0
Item_construction_year	0.0022672	0.0020911	1.0842	0.27831
Item_level_ΗΜΥΠ	0.14963	0.052008	2.8771	0.0040261
Item_level_ΙΣ	0.66303	0.046075	14.39	2.7981e-46
Item_level_ΥΠΙΣ	0.64307	0.048837	13.167	4.0229e-39
Item_level_ΗΜ	0.76383	0.070772	10.793	6.1283e-27
Item_level_1Ο	0.73002	0.045721	15.967	2.2475e-56
Item_level_2Ο	0.75806	0.045879	16.523	3.6133e-60
Item_level_3Ο	0.82124	0.045958	17.869	7.7184e-70
Item_level_4Ο	0.87287	0.045972	18.987	2.1992e-78
Item_level_5Ο	0.88329	0.046574	18.965	3.2472e-78

Item_level_6O	0.91599	0.048187	19.009	1.4769e-78
Item_level_7O	0.98539	0.14937	6.5969	4.5127e-11
Item_level_8O	0.90054	0.062005	14.524	4.272e-47
Item_energy_class_A	-0.032737	0.0098994	-3.307	0.00094798
Item_energy_class_B+	-0.05823	0.025304	-2.3013	0.021407
Item_energy_class_B	-0.071514	0.016253	-4.3999	1.0992e-05
Item_energy_class_Γ	-0.11135	0.015875	-7.0138	2.5417e-12
Item_energy_class_Δ	-0.11306	0.015843	-7.136	1.0596e-12
Item_energy_class_E	-0.15775	0.016123	-9.7842	1.8464e-22
Item_energy_class_Z	-0.14604	0.018693	-7.8128	6.4302e-15
Item_energy_class_H	-0.15349	0.015373	-9.9839	2.5865e-23
Item_condition_specific_υπό κατασκευή	1.6814	0.11457	14.675	4.9525e-48
Item_condition_specific_χρήζει ανακαίνισης	1.3406	0.11149	12.024	5.7283e-33
Item_condition_specific_καλή κατάσταση	1.182	0.1022	11.565	1.1959e-30
Item_condition_specific_ανακαινισμένο	1.2348	0.1048	11.782	9.7282e-32
Item_condition_specific_νεόδμητο	1.4058	0.13134	10.704	1.585e-26
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0097634	0.0056916	1.7154	0.086313
Item_heating_κεντρική θέρμανση	-0.090071	0.010347	-8.705	3.9325e-18
Item_heating_χωρίς θέρμανση	-0.051241	0.012952	-3.9561	7.6953e-05
Item_heating_medium_πετρέλαιο	-0.012529	0.0075062	-1.6692	0.095124
Item_heating_medium_ρεύμα	-0.028285	0.0078133	-3.6201	0.00029663
Item_heating_medium_pellet	-0.094377	0.11731	-0.8045	0.42114
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.020044	0.0017373	-11.538	1.6253e-30
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.023519	0.0022873	-10.283	1.2732e-24
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.013033	0.001607	-8.1102	5.9407e-16
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.01339	0.0017265	-7.7554	1.0082e-14
Item_construction_year:Item_condition_specific_νεόδμητο	-0.016518	0.0019705	-8.383	6.2001e-17
Item_area^2	-1.0351e-05	2.1046e-07	-49.183	0
Item_construction_year^2	0.00017721	1.4213e-05	12.468	2.7033e-35

Number of observations: 6900, Error degrees of freedom: 6849

```
Root Mean Squared Error: 0.201
R-squared: 0.839,  Adjusted R-Squared: 0.838
F-statistic vs. constant model: 716, p-value = 0

computmape =

   13.9208


ans =

  12×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	5.2931	10	0.52931	13.11	4.8122e-23
Item_area	622.19	1	622.19	15410	0
Item_construction_year	5.6946	1	5.6946	141.04	3.2547e-32
Item_level	65.203	12	5.4336	134.58	1.3602e-303
Item_energy_class	5.4391	8	0.67989	16.84	5.4029e-25
Item_condition_specific	15.706	5	3.1412	77.801	1.3112e-79
Item_heating	4.7839	3	1.5946	39.496	2.6898e-25
Item_heating_medium	0.60934	3	0.20311	5.0307	0.0017523
Item_construction_year:Item_condition_specific	8.3874	5	1.6775	41.547	2.8131e-42
Item_area^2	97.665	1	97.665	2418.9	0
Item_construction_year^2	6.2759	1	6.2759	155.44	2.7033e-35
Error	276.53	6849	0.040375		

```
mdlinter2E = 


Linear regression model:
    Transaction_price ~ [Linear formula with 12 terms in 8 predictors]

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	9.9799	0.10945	91.182	0
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Δημοδιδασκάλων	-0.058658	0.012253	-4.7873	1.7177e-06
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ ΕΡΤ	-0.015163	0.017484	-0.86726	0.38583
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Ηπείρου	-0.015751	0.0091066	-1.7296	0.083738
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Κοντόπευκο	-0.057986	0.0073081	-7.9344	2.3734e-15
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Νέα Ζωή	-0.022378	0.0099347	-2.2525	0.024312
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Παράδεισος	-0.045024	0.0083994	-5.3604	8.515e-08
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Πευκάκια	-0.14333	0.011292	-12.693	1.3433e-36
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Προφήτης Ηλίας	-0.036737	0.0093708	-3.9204	8.9075e-05
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Σταυρός	-0.005776	0.0081607	-0.70778	0.4791
level4_geo_ΑΓΙΑ ΠΑΡΑΣΚΕΥΗ Τσακός	-0.040376	0.011986	-3.3685	0.00075912
Item_area	0.0090946	6.9614e-05	130.64	0
Item_construction_year	0.001673	0.0019134	0.87438	0.38193
Item_level_ΗΜΙΥΠ	0.041601	0.044537	0.93407	0.3503
Item_level_ΙΣ	0.56274	0.038646	14.561	1.7561e-47
Item_level_ΥΠΙΣ	0.51265	0.041211	12.44	3.1391e-35
Item_level_ΗΜ	0.65077	0.066704	9.7561	2.2546e-22
Item_level_1O	0.63215	0.038338	16.489	3.5023e-60
Item_level_2O	0.65935	0.038455	17.146	7.5264e-65
Item_level_3O	0.72667	0.038501	18.874	6.3154e-78
Item_level_4O	0.78333	0.038517	20.337	6.8143e-90
Item_level_5O	0.79828	0.039013	20.462	5.9698e-91

Item_level_6O	0.83644	0.04039	20.709	4.599e-93
Item_level_7O	0.90129	0.14884	6.0553	1.4592e-09
Item_level_8O	0.79184	0.051833	15.277	5.0615e-52
Item_energy_class_A	-0.033761	0.0090706	-3.722	0.00019885
Item_energy_class_B+	-0.060562	0.021882	-2.7676	0.0056583
Item_energy_class_B	-0.078222	0.01371	-5.7053	1.1987e-08
Item_energy_class_Γ	-0.096119	0.013631	-7.0514	1.9044e-12
Item_energy_class_Δ	-0.10441	0.013491	-7.7391	1.1121e-14
Item_energy_class_E	-0.14482	0.013811	-10.486	1.4163e-25
Item_energy_class_Z	-0.13808	0.01613	-8.5603	1.3154e-17
Item_energy_class_H	-0.13847	0.012515	-11.064	2.8736e-28
Item_condition_specific_υπό κατασκευή	1.8739	0.10924	17.153	6.7379e-65
Item_condition_specific_χρήζει ανακαίνισης	1.4993	0.10497	14.284	8.9723e-46
Item_condition_specific_καλή κατάσταση	1.3936	0.097099	14.352	3.4171e-46
Item_condition_specific_ανακαινισμένο	1.4025	0.099233	14.133	7.2981e-45
Item_condition_specific_νεόδμητο	1.581	0.12319	12.834	2.2817e-37
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0094711	0.0051345	1.8446	0.065126
Item_heating_κεντρική θέρμανση	-0.088223	0.0091507	-9.6411	6.8733e-22
Item_heating_χωρίς θέρμανση	-0.021281	0.011216	-1.8975	0.057797
Item_heating_medium_πετρέλαιο	-0.012725	0.0067065	-1.8974	0.057814
Item_heating_medium_ρεύμα	-0.03231	0.0071061	-4.5468	5.5205e-06
Item_heating_medium_pellet	0.021848	0.10283	0.21248	0.83174
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.022383	0.001653	-13.541	2.3344e-41
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.024303	0.0021	-11.573	9.4542e-31
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.015525	0.0015234	-10.191	2.9661e-24
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.014454	0.0016229	-8.9063	6.3315e-19
Item_construction_year:Item_condition_specific_νεόδμητο	-0.018493	0.0018484	-10.005	1.9338e-23
Item_area^2	-7.8892e-06	1.0808e-07	-72.994	0
Item_construction_year^2	0.00021084	1.2043e-05	17.507	1.7456e-67

Number of observations: 8860, Error degrees of freedom: 8809

```
Root Mean Squared Error: 0.203
R-squared: 0.833,  Adjusted R-Squared: 0.832
F-statistic vs. constant model: 881, p-value = 0

computmape =

   14.3828


ans =

  12×5 table
```

	SumSq	DF	MeanSq	F	pValue
level4_geo	8.7821	10	0.87821	21.246	1.2981e-39
Item_area	703.25	1	703.25	17013	0
Item_construction_year	8.9924	1	8.9924	217.55	1.1767e-48
Item_level	91.611	12	7.6343	184.69	0
Item_energy_class	6.2749	8	0.78436	18.975	1.497e-28
Item_condition_specific	24.983	5	4.9966	120.88	4.1736e-124
Item_heating	5.5438	3	1.8479	44.706	1.1526e-28
Item_heating_medium	0.92851	3	0.3095	7.4876	5.2945e-05
Item_construction_year:Item_condition_specific	10.654	5	2.1308	51.549	7.2868e-53
Item_area^2	220.24	1	220.24	5328.1	0
Item_construction_year^2	12.669	1	12.669	306.49	1.7456e-67
Error	364.12	8809	0.041335		

mdlinter3B =

Linear regression model:
    Transaction_price ~ [Linear formula with 11 terms in 7 predictors]

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	9.9002	0.14737	67.179	0
Item_area	0.0048616	4.6415e-05	104.74	0
Item_construction_year	0.0095427	0.0026299	3.6285	0.00028668
Item_level_ΗΜΙΥΠ	0.065927	0.050468	1.3063	0.19149
Item_level_ΙΣ	0.76884	0.043286	17.762	2.2775e-69
Item_level_ΥΠΙΣ	0.75522	0.047215	15.995	8.7585e-57
Item_level_ΗΜ	0.85952	0.077006	11.162	9.796e-29
Item_level_1Ο	0.83089	0.04282	19.404	3.744e-82
Item_level_2Ο	0.86461	0.043061	20.079	1.053e-87
Item_level_3Ο	0.96387	0.043068	22.38	6.2717e-108
Item_level_4Ο	1.0185	0.043095	23.635	9.048e-120
Item_level_5Ο	1.0799	0.043855	24.624	1.6486e-129
Item_level_6Ο	1.1741	0.045915	25.57	3.8531e-139
Item_level_7Ο	1.1989	0.11589	10.345	6.1617e-25
Item_level_8Ο	1.0457	0.062391	16.76	4.4231e-62
Item_energy_class_A	-0.059566	0.01161	-5.1307	2.9481e-07
Item_energy_class_B+	-0.060206	0.02179	-2.763	0.0057388
Item_energy_class_B	-0.11972	0.019252	-6.2184	5.2532e-10
Item_energy_class_Γ	-0.13853	0.016753	-8.269	1.5485e-16
Item_energy_class_Δ	-0.13666	0.017658	-7.7392	1.112e-14
Item_energy_class_E	-0.16073	0.017468	-9.2009	4.3699e-20
Item_energy_class_Z	-0.17053	0.021486	-7.9368	2.3299e-15

Item_energy_class_H	-0.15483	0.017805	-8.6959	4.0638e-18
Item_condition_specific_υπό κατασκευή	1.9256	0.14926	12.901	9.751e-38
Item_condition_specific_χρήζει ανακαίνισης	1.4667	0.13635	10.757	8.091e-27
Item_condition_specific_καλή κατάσταση	1.4958	0.13424	11.143	1.2109e-28
Item_condition_specific_ανακαινισμένο	1.4403	0.13738	10.484	1.4465e-25
Item_condition_specific_νεόδμητο	1.7789	0.17099	10.403	3.3532e-25
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.012809	0.0066011	1.9404	0.052362
Item_heating_κεντρική θέρμανση	-0.080754	0.011133	-7.2535	4.4071e-13
Item_heating_χωρίς θέρμανση	0.0027027	0.015843	0.17059	0.86455
Item_heating_medium_πετρέλαιο	0.0055045	0.0082854	0.66437	0.50647
Item_heating_medium_ρεύμα	-0.059275	0.009439	-6.2799	3.5504e-10
Item_heating_medium_pellet	0.085602	0.11851	0.72232	0.47012
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.023811	0.0022561	-10.554	6.9523e-26
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.018404	0.0022021	-8.3576	7.3823e-17
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.017712	0.0020966	-8.448	3.4397e-17
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.015796	0.0022462	-7.032	2.1882e-12
Item_construction_year:Item_condition_specific_νεόδμητο	-0.021884	0.0025332	-8.6389	6.679e-18
Item_area^2	-5.9953e-07	7.1078e-09	-84.348	0
Item_construction_year^2	0.00015057	1.6242e-05	9.2705	2.2964e-20

Number of observations: 8790, Error degrees of freedom: 8749
Root Mean Squared Error: 0.263

R-squared: 0.736, Adjusted R-Squared: 0.735
F-statistic vs. constant model: 610, p-value = 0

computmape =

21.3747

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.109883e-16.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Binter2 (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.490119e-16.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Binter2 (line 38)


ans =

  11×5 table
```

	SumSq	DF	MeanSq	F	pValue
Item_area	269.12	1	269.12	3878	0
Item_construction_year	13.275	1	13.275	191.3	4.6934e-43
Item_level	173.14	12	14.429	207.92	0
Item_energy_class	6.959	8	0.86987	12.535	4.8174e-18
Item_condition_specific	15.051	5	3.0103	43.378	2.4913e-44
Item_heating	5.7353	3	1.9118	27.549	1.0037e-17
Item_heating_medium	2.9119	3	0.97063	13.987	4.2906e-09
Item_construction_year:Item_condition_specific	9.512	5	1.9024	27.414	1.2486e-27
Item_area^2	493.73	1	493.73	7114.6	0
Item_construction_year^2	5.964	1	5.964	85.942	2.2964e-20
Error	607.14	8749	0.069396		

```
mdlinter3D =


Linear regression model:
    Transaction_price ~ [Linear formula with 11 terms in 7 predictors]

Estimated Coefficients:
```

	Estimate	SE	tStat	pValue
(Intercept)	9.9567	0.14925	66.713	0
Item_area	0.0049369	4.7906e-05	103.05	0
Item_construction_year	0.0077286	0.0026849	2.8785	0.0040058
Item_level_ΗΜΙΥΠ	0.065129	0.050548	1.2884	0.19763
Item_level_ΙΣ	0.76697	0.043439	17.656	1.6881e-68
Item_level_ΥΠΙΣ	0.75048	0.047633	15.755	4.0524e-55
Item_level_ΗΜ	0.85044	0.077132	11.026	4.5215e-28
Item_level_1Ο	0.82695	0.042947	19.255	7.7344e-81
Item_level_2Ο	0.85986	0.04319	19.909	3.653e-86
Item_level_3Ο	0.96128	0.043205	22.249	1.5832e-106
Item_level_4Ο	1.0121	0.043251	23.401	2.7965e-117
Item_level_5Ο	1.0726	0.044081	24.332	2.5598e-126
Item_level_6Ο	1.1652	0.04644	25.09	6.7658e-134
Item_level_7Ο	1.1957	0.11607	10.301	9.8391e-25
Item_level_8Ο	1.0445	0.06343	16.467	5.8107e-60
Item_energy_class_A	-0.050967	0.012086	-4.217	2.5024e-05
Item_energy_class_B+	-0.056389	0.022309	-2.5276	0.011503
Item_energy_class_B	-0.11746	0.020124	-5.8365	5.5327e-09
Item_energy_class_Γ	-0.13585	0.017387	-7.8136	6.2498e-15
Item_energy_class_Δ	-0.13768	0.018363	-7.4979	7.1648e-14
Item_energy_class_E	-0.16257	0.018064	-9.0001	2.7659e-19
Item_energy_class_Z	-0.17429	0.022095	-7.8883	3.4589e-15

Item_energy_class_H	-0.15897	0.0184	-8.6395	6.7151e-18
Item_condition_specific_υπό κατασκευή	1.8975	0.15224	12.464	2.439e-35
Item_condition_specific_χρήζει ανακαίνισης	1.4147	0.13811	10.243	1.7814e-24
Item_condition_specific_καλή κατάσταση	1.4554	0.13594	10.706	1.4241e-26
Item_condition_specific_ανακαινισμένο	1.4155	0.13916	10.171	3.7094e-24
Item_condition_specific_νεόδμητο	1.7277	0.17269	10.004	1.9887e-23
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.013131	0.0068488	1.9173	0.05523
Item_heating_κεντρική θέρμανση	-0.084277	0.011435	-7.3703	1.8686e-13
Item_heating_χωρίς θέρμανση	0.00027353	0.016454	0.016624	0.98674
Item_heating_medium_πετρέλαιο	0.0061915	0.0085027	0.72818	0.46652
Item_heating_medium_ρεύμα	-0.061398	0.0098387	-6.2404	4.5803e-10
Item_heating_medium_pellet	0.077431	0.13267	0.58364	0.55948
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.023014	0.0023101	-9.9622	3.0246e-23
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.017108	0.0022454	-7.6189	2.8438e-14
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.016762	0.0021368	-7.8445	4.8946e-15
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.015239	0.0022904	-6.6535	3.0453e-11
Item_construction_year:Item_condition_specific_νεόδμητο	-0.020834	0.002571	-8.1035	6.1136e-16
Item_area^2	-6.0804e-07	7.2566e-09	-83.792	0
Item_construction_year^2	0.00015851	1.6668e-05	9.5097	2.4645e-21

```
Number of observations: 8222, Error degrees of freedom: 8181
Root Mean Squared Error: 0.264
R-squared: 0.738,  Adjusted R-Squared: 0.737
F-statistic vs. constant model: 578, p-value = 0

computmape =

   21.2726
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.087641e-16.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Dinter (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.457875e-16.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Dinter (line 38)


ans =

  11×5 table
```

	SumSq	DF	MeanSq	F	pValue
Item_area	251.8	1	251.8	3619.6	0
Item_construction_year	11.067	1	11.067	159.09	3.873e-36
Item_level	162.1	12	13.509	194.18	0
Item_energy_class	6.5411	8	0.81764	11.754	8.9272e-17
Item_condition_specific	16.183	5	3.2367	46.527	1.4161e-47
Item_heating	5.9065	3	1.9688	28.302	3.3669e-18
Item_heating_medium	2.8805	3	0.96017	13.802	5.6339e-09
Item_construction_year:Item_condition_specific	8.3249	5	1.665	23.934	5.5661e-24
Item_area^2	488.42	1	488.42	7021	0

Item_construction_year^2	6.2911	1	6.2911	90.434	2.4645e-21
Error	569.12	8181	0.069566		

mdlinter3E =

Linear regression model:
    Transaction_price ~ [Linear formula with 11 terms in 7 predictors]

Estimated Coefficients:

	Estimate	SE	tStat	pValue
(Intercept)	10.123	0.13302	76.102	0
Item_area	0.0050574	4.1627e-05	121.49	0
Item_construction_year	0.0041544	0.0023582	1.7616	0.078157
Item_level_ΗΜΙΥΠ	-0.0046674	0.041233	-0.1132	0.90988
Item_level_ΙΣ	0.66194	0.035627	18.58	6.8468e-76
Item_level_ΥΠΙΣ	0.62173	0.039026	15.931	1.6549e-56
Item_level_ΗΜ	0.73446	0.072403	10.144	4.497e-24
Item_level_1Ο	0.71973	0.035198	20.448	3.149e-91
Item_level_2Ο	0.75391	0.035401	21.296	1.2175e-98
Item_level_3Ο	0.84988	0.035421	23.994	4.9878e-124
Item_level_4Ο	0.90991	0.035452	25.666	4.0043e-141
Item_level_5Ο	0.96132	0.036198	26.558	1.1734e-150
Item_level_6Ο	1.0497	0.038152	27.514	3.4158e-161
Item_level_7Ο	1.0768	0.11213	9.603	9.46e-22
Item_level_8Ο	0.93065	0.051535	18.059	7.4115e-72
Item_energy_class_A	-0.051799	0.010154	-5.1011	3.4328e-07
Item_energy_class_B+	-0.072012	0.019734	-3.6492	0.00026426
Item_energy_class_B	-0.09846	0.016318	-6.0337	1.6547e-09
Item_energy_class_Γ	-0.12698	0.014838	-8.558	1.3016e-17
Item_energy_class_Δ	-0.12486	0.015757	-7.9241	2.5219e-15
Item_energy_class_E	-0.1511	0.015513	-9.7401	2.5052e-22

Item_energy_class_Ζ	-0.15037	0.01853	-8.1151	5.3752e-16
Item_energy_class_Η	-0.16519	0.016014	-10.315	7.8296e-25
Item_condition_specific_υπό κατασκευή	1.8614	0.13842	13.447	6.7568e-41
Item_condition_specific_χρήζει ανακαίνισης	1.3897	0.12448	11.163	8.7998e-29
Item_condition_specific_καλή κατάσταση	1.4404	0.12283	11.726	1.4401e-31
Item_condition_specific_ανακαινισμένο	1.3503	0.12544	10.765	6.8966e-27
Item_condition_specific_νεόδμητο	1.6674	0.15522	10.742	8.7891e-27
Item_heating_αυτόνομη θέρμανση με κεντρική εγκατάσταση	0.0097478	0.0059038	1.6511	0.098742
Item_heating_κεντρική θέρμανση	-0.068905	0.0094368	-7.3017	3.0382e-13
Item_heating_χωρίς θέρμανση	0.01933	0.013799	1.4009	0.16128
Item_heating_medium_πετρέλαιο	0.009828	0.007324	1.3419	0.17966
Item_heating_medium_ρεύμα	-0.061349	0.0086591	-7.0849	1.4771e-12
Item_heating_medium_pellet	0.14187	0.10706	1.3252	0.18513
Item_construction_year:Item_condition_specific_υπό κατασκευή	-0.022573	0.0021004	-10.747	8.3255e-27
Item_construction_year:Item_condition_specific_χρήζει ανακαίνισης	-0.016409	0.0020121	-8.1551	3.8698e-16
Item_construction_year:Item_condition_specific_καλή κατάσταση	-0.016596	0.0019321	-8.5896	9.9143e-18
Item_construction_year:Item_condition_specific_ανακαινισμένο	-0.013515	0.0020558	-6.5742	5.1149e-11
Item_construction_year:Item_condition_specific_νεόδμητο	-0.019871	0.0023139	-8.5875	1.0089e-17
Item_area^2	-6.2457e-07	6.6071e-09	-94.53	0
Item_construction_year^2	0.00019432	1.3849e-05	14.031	2.4315e-44

```
Number of observations: 10983, Error degrees of freedom: 10942
Root Mean Squared Error: 0.261
R-squared: 0.741,  Adjusted R-Squared: 0.74
F-statistic vs. constant model: 782, p-value = 0

computmape =

   21.2109

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.348308e-16.
```

```
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Einter2 (line 38)

Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  1.755286e-16.
> In classreg.regr.CompactLinearModel>getTermSS1 (line 1447)
In classreg.regr/CompactLinearModel/componentanova (line 830)
In classreg.regr/CompactLinearModel/anova (line 335)
In realestcatmapefinsens53Einter2 (line 38)


ans =

  11×5 table
```

	SumSq	DF	MeanSq	F	pValue
Item_area	397.46	1	397.46	5855.9	0
Item_construction_year	14.149	1	14.149	208.46	8.0282e-47
Item_level	210.77	12	17.564	258.78	0
Item_energy_class	8.3579	8	1.0447	15.392	1.0165e-22
Item_condition_specific	19.928	5	3.9856	58.722	1.5761e-60
Item_heating	5.7778	3	1.9259	28.375	2.8634e-18
Item_heating_medium	3.8412	3	1.2804	18.864	3.3676e-12
Item_construction_year:Item_condition_specific	10.362	5	2.0725	30.535	5.9785e-31
Item_area^2	606.51	1	606.51	8936	0
Item_construction_year^2	13.362	1	13.362	196.87	2.4315e-44
Error	742.67	10942	0.067873		