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Modeling demand factors for sustainable reconstruction: Insights from Türkiye's earthquake-affected real estate market

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Abstract

The devastating impacts of the February 2023 earthquakes in Türkiye have underscored the urgent need for resilient and sustainable reconstruction in disaster-affected areas. This research paper explores the potential for low carbon investments in the real estate sector to drive the recovery and redevelopment of earthquake-impacted regions. By leveraging demand modeling techniques and analyzing key market indicators, the study aims to identify investment opportunities that can deliver both economic and environmental benefits. The paper draws upon a comprehensive dataset spanning 81 cities from 2013 to 2022, enabling a robust analysis of residential market dynamics, energy consumption patterns, and socioeconomic factors. Through the application of random-effects GLS regression, the research uncovers the determinants of housing demand and the viability of low carbon interventions in post-disaster settlements. The findings offer valuable insights for policymakers, investors, and real estate professionals seeking to promote sustainable and resilient reconstruction efforts. By highlighting the potential for low carbon investments to stimulate economic recovery while mitigating climate change impacts, this paper contributes to the growing body of knowledge on green real estate and disaster risk management.

Keywords: low carbon real estate, disaster recovery, demand modeling, resilient reconstruction, sustainable investments

1. Introduction

The February 2023 earthquakes in Türkiye have caused unprecedented damage to the built environment, displacing millions of people and disrupting economic activities. As the affected regions embark on the path to recovery, there is a critical need to ensure that reconstruction efforts prioritize resilience and sustainability. Low carbon investments in the real estate sector present a promising avenue for achieving these goals while catalyzing economic growth and job creation.

This research paper investigates the potential for low carbon real estate investments to drive the resilient reconstruction of earthquake-affected areas in Türkiye. By analyzing market trends, energy consumption patterns, and socioeconomic indicators, the study aims to identify investment opportunities that can deliver both environmental and economic returns. The paper builds upon existing literature on green real estate, post-disaster reconstruction, and demand modeling techniques to provide a comprehensive assessment of the viability and impact of low carbon interventions in disaster-affected settlements.

The remainder of the paper is structured as follows: Section 2 reviews the relevant literature on low carbon real estate, post-disaster reconstruction challenges, and demand modeling approaches.

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Section 3 describes the data and methodology employed in the study, with a focus on the random-effects GLS regression model. Section 4 presents the key findings and discusses their implications for policy and practice. Finally, Section 5 concludes with a summary of the main contributions and avenues for future research.

2. Literature Review

The growing concern over climate change and the need for sustainable development has led to an increased focus on low carbon investments in the real estate sector. This literature review aims to explore the existing research on low carbon investments in post-disaster reconstruction, with a particular emphasis on the case of Türkiye. The review will also examine the application of demand modeling techniques to assess the market demand and uptake of low carbon real estate. By synthesizing the findings from various studies, this review seeks to provide valuable insights into the challenges, opportunities, and potential impacts of low carbon investments in post-disaster settings.

Post-disaster reconstruction presents unique challenges and opportunities for incorporating low carbon investments in the real estate sector. Twigg (2021) highlights the lack of adequate planning and coordination in the establishment of post-disaster settlements as a major challenge. This lack of coordination can lead to the development of unsustainable and inefficient built environments, further exacerbating the vulnerability of communities to future disasters. Land tenure and property rights issues also pose significant challenges in post-disaster settlements (Fan, 2012). The lack of clear land ownership and the need for rapid reconstruction can lead to the development of informal settlements, which often lack access to basic services and infrastructure. This can hinder the implementation of low carbon investments, as the absence of secure land tenure can discourage long-term investments in energy-efficient buildings and renewable energy systems.

Another critical challenge in post-disaster settlements is the need to balance short-term humanitarian needs with long-term development goals (Kennedy et al., 2008). In the immediate aftermath of a disaster, the focus is often on providing shelter, food, and medical aid to affected communities. However, the reconstruction process also presents an opportunity to build back better, incorporating sustainable design principles and low carbon technologies. Striking a balance between these short-term and long-term objectives requires careful planning and coordination among various stakeholders. Strong governance structures and effective institutions are crucial for ensuring the successful implementation of low carbon investments in post-disaster reconstruction. This includes the development of supportive policies, building codes, and incentive mechanisms that encourage the adoption of energy-efficient practices and renewable energy technologies.

In Bucharest's real estate market, a hedonic analysis reveals that energy-efficient retrofitted properties achieve a "green premium" of 2.2% to 6.5%, depending on location, highlighting how specific attributes like energy efficiency boost property values. Similarly, analyzing house price patterns before and after the 2012 Van earthquake demonstrates that perceived risks, such as natural disasters, affect submarkets differently, with cheaper areas facing more significant negative impacts. These cases reveal the limitations of standard hedonic models in capturing complex, granular influences like environmental hazards or energy efficiency, emphasizing the need for advanced frameworks, such as multi-level event studies, to isolate neighborhood-level effects and provide clearer insights into spatially segmented markets (Keskin et al., 2017; Taltavull et al., 2017).

Energy efficiency improvements enhance property values, generating "green premiums" of 2.2–7.4% due to reduced risks of regulatory value loss and indirect benefits like reputation and health. However, uneven access to retrofitting subsidies, such as Sweden's ROT subsidy, exacerbates regional disparities by favoring wealthier areas, highlighting the need for equitable policies. Similarly, energy performance certificates (EPCs) have a limited but positive impact on property values, with energy efficiency contributing rental premiums of 0.2–8.2% depending on rating, though low-rated properties face discounts of 3.9–5.5%. These variations reveal a "split-incentive dilemma," where landlords bear high costs while tenants lack long-term incentives, necessitating financial incentives, education, and regulation (Taltavull et al., 2017; Wilhelmsson & Warsame, 2024; McCord et al., 2024).

The economic and financial viability of low carbon investments in the real estate sector is a key factor in their uptake and success. Kok et al. (2012) found that green-certified buildings, which often incorporate energy efficiency measures, command rental premiums of 3-8% and sale premiums of 13% compared to non-certified buildings. This suggests that investments in energy efficiency can enhance the financial performance of real estate assets, providing a compelling case for their adoption. Zhang et al. (2011) demonstrated the feasibility and economic viability of integrating solar photovoltaics into a high-rise residential building in China. The study found that the solar system could provide 20% of the building's electricity needs and achieve a payback period of 7.3 years. This highlights the potential for renewable energy technologies to reduce operational costs and generate long-term financial benefits for building owners and occupants. Collins and Junghans (2015) explored the potential of green leases in the Norwegian commercial real estate sector, highlighting the benefits and challenges of implementing such arrangements. Green leases can align the interests of building owners and tenants, encouraging the adoption of energy-efficient practices and the sharing of costs and benefits associated with low carbon investments. However, the study also notes the need for clear communication, data sharing, and performance monitoring to ensure the effectiveness of green leases.

Demand modeling techniques have been applied to assess the market demand and uptake of low carbon real estate. Fuerst et al. (2015) applied hedonic pricing to analyze the effect of Energy Performance Certificates (EPCs) on the rental and sale prices of commercial properties in the UK. The results showed that properties with higher EPC ratings commanded significant price premiums, indicating a market demand for energy-efficient buildings. This suggests that investing in energy efficiency improvements can not only reduce operational costs but also increase the value and marketability of real estate assets.

Zhang et al. (2018) applied a hedonic pricing model to analyze the price premium of LEED-certified office buildings in the United States. The study found that LEED-certified buildings commanded a significant rental and sale price premium compared to non-certified buildings, indicating a market recognition of the benefits of green building certification. This highlights the importance of third-party certification in signaling the value and quality of low carbon real estate to potential buyers and tenants. Fuerst and McAllister (2011) employed hedonic pricing to analyze the effect of energy performance certificates on the rental and sale prices of commercial properties in the UK. The results indicated that properties with higher energy efficiency ratings commanded significant price premiums, suggesting a willingness to pay for low carbon attributes. This underscores the potential for energy efficiency to create market differentiation and competitive advantage in the real estate sector. In addition to the previously discussed studies, several other papers have explored the topic of low carbon investments in the real estate sector, particularly in the context of post-disaster reconstruction and demand modeling. Nguyen et al. (2017) investigated the factors influencing the adoption of green building practices in Vietnam, a country prone to natural disasters. The study found that government support, market demand, and stakeholder awareness were key drivers of green building adoption. The authors also highlighted the need for capacity building and technology transfer to promote sustainable reconstruction practices in developing countries. This study underscores the importance of policy interventions and market signals in shaping the uptake of low carbon investments in post-disaster settings.

Kontokosta (2016) applied machine learning techniques to predict energy consumption in buildings using a large dataset of energy audits in New York City. The study demonstrated the potential of data-driven approaches to inform energy efficiency policies and prioritize retrofit investments. By identifying the most influential building characteristics and occupancy patterns, the model can help building owners and policymakers target their energy efficiency efforts more effectively. This highlights the value of demand modeling in optimizing low carbon investments and maximizing their impact.

Matisoff et al. (2016) examined the effectiveness of state-level green building incentives in the United States using a difference-in-differences approach. The study found that states with green building incentives experienced a significant increase in LEED registrations and certifications compared to states without such incentives. The authors also noted that the impact of incentives varied by building type and ownership, with larger effects observed for government-owned and institutional buildings. This study highlights the role of policy incentives in driving the adoption of low carbon building practices and the potential for targeted interventions to accelerate the transition towards a sustainable built environment. Martek et al. (2019) conducted a systematic review of the literature on green building rating systems and their impact on the real estate market. The review identified several key themes, including the financial benefits of green building certification, the role of government policies and incentives, and the importance of market demand and consumer preferences. The authors also noted the limitations of current rating systems, such as their focus on individual buildings rather than the broader urban context and the lack of consideration for social and economic sustainability. This review provides a comprehensive overview of the state of knowledge on green building rating systems and highlights the need for more holistic and context-specific approaches to low carbon real estate development.

Chegut et al. (2019) applied a spatial hedonic pricing model to analyze the impact of energy efficiency and sustainability features on the rental prices of commercial properties in London, UK. The study found that properties with higher Energy Performance Certificate (EPC) ratings and BREEAM certifications commanded significant rental premiums, with the effect being more pronounced in central locations and for larger properties. The authors also noted the presence of spatial spillover effects, with properties in close proximity to green buildings also benefiting from higher rental prices. This study demonstrates the importance of considering spatial factors in the analysis of low carbon real estate and the potential for green buildings to generate positive externalities and enhance the value of surrounding properties. Environment Quality is measured by several vulnerability indicators, including health, infrastructure, social capital, and flood risks. Higher vulnerability in these aspects tends to lower land value as these factors negatively impact the desirability and functionality of the location. Additionally, areas with lower social and physical risks are associated with higher land values due to increased attractiveness for residential or commercial use (Gamal et al., 2023).

The interplay of urban environmental governance, informality, and precarity highlights that displacement and improvement cannot be fully understood through environmental gentrification alone. Postcolonial development dynamics reveal that diverse groups—from slum residents to middle-class activists—shape environmental subjectivities based on class, gender, and socio-political factors, influencing their support for or resistance to market-driven development projects that perpetuate environmental injustices. As urban areas promote climate-friendly living, middle- and upper-income residents prefer transit-oriented, pedestrian-friendly, and mixed-use neighborhoods, raising property values and displacing lower-income, often non-white residents. These trends underline the need for housing justice and sustainability efforts to ensure the benefits of eco-friendly urban development are equitably shared, especially given that affluent residents continue to have larger carbon footprints despite lower emissions from transportation and buildings (Doshi, 2018; Rice et al., 2019).

Darko et al. (2017) investigated the drivers and barriers to green building adoption in developing countries through a survey of construction professionals in Ghana. The study identified several key drivers, including environmental concerns, government support, and market demand, as well as barriers such as the lack of awareness, higher upfront costs, and the lack of technical expertise. The authors also highlighted the need for capacity building, technology transfer, and the development of locally relevant green building rating systems to promote sustainable construction practices in developing countries. This study provides valuable insights into the challenges and opportunities for low carbon real estate development in the context of developing economies and the importance of tailoring interventions to local needs and capacities.

This expanded literature review has explored additional studies on low carbon investments in the real estate sector, with a focus on post-disaster reconstruction, demand modeling, and the drivers and barriers to adoption. The review highlights the importance of government policies and incentives, market demand and consumer preferences, capacity building and technology transfer, and the development of locally relevant green building rating systems in promoting the uptake of low carbon real estate. The studies also demonstrate the value of demand modeling techniques, such as hedonic pricing, discrete choice experiments, and machine learning, in understanding the market demand for green building attributes and informing the design and marketing of low carbon real estate products.

However, the review also notes the challenges and limitations of current approaches to low carbon real estate development, such as the focus on individual buildings rather than the broader urban context, the lack of consideration for social and economic sustainability, and the need for more holistic and context-specific approaches. As the real estate sector continues to pursue sustainability goals, future research should focus on addressing these challenges and exploring innovative solutions that can accelerate the transition towards a low carbon built environment while promoting social equity and economic resilience. Future research should focus on addressing these challenges and exploring innovative approaches to demand modeling that can better capture the complex interactions between technological, economic, social, and policy factors influencing the uptake of low carbon real estate. Empirical studies that evaluate the effectiveness of different policy interventions and market strategies in promoting low carbon investments, particularly in post-disaster settings, would also be valuable. Finally, research that examines the long-term impacts and co-benefits of low carbon investments, such as improved health and well-being, increased resilience, and job creation, can further strengthen the case for their adoption in the real estate sector.

3. Model

The rapid urbanization and economic development in Türkiye have led to significant changes in the real estate market, energy consumption patterns, and socioeconomic factors across the country. To better understand these dynamics and their implications for sustainable urban development, it is crucial to analyze the relationships between various indicators using robust statistical techniques. This study employs a random-effects GLS regression model to investigate the determinants of energy consumption per capita (K_MES) in 81 cities in Türkiye, using a comprehensive panel dataset spanning from 2013 to 2022.The provided data summary table presents a comprehensive overview of a panel dataset consisting of 81 cities in Türkiye, spanning a timeframe from 2013 to 2022. The table includes various key indicators related to the real estate market, demographics, economic factors, and energy consumption.

The Table 1 focus on sales data for different types of properties. S ILK represents the first sales, S IKIEL represents the second sales, S IPO represents mortgage sales, and S TOP represents the total sales. These variables provide insights into the overall health and activity of the real estate market in the cities included in the dataset. The mean values for these variables range from 4,934.669 for mortgage sales to 16,705.865 for total sales, indicating a significant volume of real estate transactions across the cities. The maximum values for these variables are substantially higher than the mean, suggesting the presence of cities with particularly high levels of real estate activity. The minimum values, on the other hand, are relatively low, indicating that some cities may have comparatively less active real estate markets. The next two rows provide demographic information, with N TOP representing the total population and N HIZ P representing the population growth rate. The mean population across the cities is 1,003,041.1, with a maximum of 15,907,951 and a minimum of 75,620. This wide range suggests that the dataset includes both large metropolitan areas and smaller cities. The population growth rate has a mean of 8.641%, with a maximum of 151% and a minimum of -149%, indicating that some cities have experienced significant population changes during the study period. The following three rows present economic indicators. EV TGE represents the cost of living indices, with a mean value of 85.587 and a relatively narrow range, suggesting that the cost of living is somewhat consistent across the cities. EV DA represents the dollar exchange rate, which has a mean of 5.642 and a maximum of 16.564, reflecting the fluctuations in the value of the Turkish lira against the US dollar during the study period. EV BTL represents the bank interest rate, with a mean of 17.463% and a maximum of 28.788%, indicating relatively high borrowing costs in Türkiye.

The last two rows focus on energy consumption. K MES represents the energy consumption per capita, with a mean of 571.519 and a maximum of 1,295, suggesting significant variations in energy usage across the cities. KO KS represents the total number of residential units, with a mean of 436,882.23 and a maximum of 6,505,304, highlighting the substantial housing stock in the cities included in the dataset. Finally, H MES represents the total housing energy consumption, with a mean of 652,314.59 and a maximum of 12,469,516. The minimum value of 0 suggests that some cities may have missing data for this variable.

Table 1 Summary of Dataset

	Mean	Max	Min	SD	Median	IQR
S ILK	6809.049	114732	57.000	12603.189	3111	6246
S IKIEL	9936.11	201072	18.000	20596.137	3698	8103
S IPO	4934.669	106977	9.000	11038.306	1751	4036
S TOP	16705.865	276223	124.000	32549.588	6875	14809
N TOP	1003041.1	15907951	75620.000	1812556	530271.5	770872
N HIZ	8.641	151	-149.000	17.772	9	15
EV TGE	85.587	93.816	71.404	7.034	87.987	11.888
EV DA	5.642	16.564	1.901	4.218	4.231	4.289
EV BTL	17.463	28.788	10.912	5.536	14.645	9.29
K MES	571.519	1295	130.000	161.432	565	197
KO KS	436882.23	6505304	33255.000	729522.26	227982	359992
H MES	652314.59	12469516	0.000	1387496.9	269250.5	485332.5

Random-effects GLS regression is a type of multilevel or hierarchical linear model that is used to analyze data with a nested structure, such as individuals (level 1) nested within groups or clusters (level 2). The key feature of this model is that it allows for the estimation of both fixed effects (the effects of the independent variables) and random effects (the unobserved heterogeneity at the group level).

The general model can be expressed as:

$Y\_ij = \beta_o + \Sigma\ \beta_k * X_{kij} + u_j + e_{ij}$

Where:

Y_ij is the dependent variable for individual i in group j

$X_{1ij}, X_{2ij}, \ldots, X_{kij}$ are the independent variables

$\beta_0, \beta_1, \ldots, \beta_k$ are the fixed-effect coefficients

u_j is the random effect for group j

e_{ij} is the individual-level error term

Random-effects GLS (Generalized Least Squares) regression is a powerful statistical technique used to analyze hierarchical or multilevel data, where observations are nested within groups or clusters. This model is particularly useful when dealing with panel data, where multiple observations are collected for each individual or unit over time. The random-effects GLS regression model accounts for both the fixed effects of the independent variables and the random effects of the unobserved heterogeneity at the group level.

In the context of the given model, Y_{ij} represents the dependent variable for individual i in group j. This could be, for example, the housing demand for a specific city (i) in a particular year (j). The independent variables, denoted as $X_{1ij}, X_{2ij}, \ldots, X_{kij}$, are the factors that are believed to influence the dependent variable. These could include variables such as the energy performance of buildings, economic indicators, market dynamics, socioeconomic factors, and disaster impact, as mentioned in the previous discussion.

The fixed-effect coefficients, represented by $\beta_0, \beta_1, \ldots, \beta_k$, capture the average effect of each independent variable on the dependent variable, holding all other variables constant. These coefficients are assumed to be the same for all groups or clusters, hence the term "fixed effects." The interpretation of these coefficients is straightforward: a one-unit increase in X_{kij} is associated with a β_k unit change in Y_{ij}, on average, while holding all other variables constant. The random effect, denoted as u_j, captures the unobserved heterogeneity at the group level. In the context of the given model, this could represent the unique characteristics of each city that are not accounted for by the independent variables. These unobserved factors could include geographical features, cultural aspects, or historical events specific to each city. The random effect is assumed to be normally distributed with a mean of zero and a constant variance, and it is uncorrelated with the independent variables and the individual-level error term.

The individual-level error term, e_{ij}, represents the unexplained variation in the dependent variable at the individual level. This term captures the idiosyncratic factors that affect housing demand for each observation, which are not accounted for by the independent variables or the group-level random effect.

The random-effects GLS regression model has several advantages over other regression techniques. First, it allows for the estimation of both fixed and random effects, providing a more comprehensive understanding of the relationships between the variables. Second, by accounting for the nested structure of the data, the model produces more accurate and efficient estimates of the coefficients, as it takes into account the correlation between observations within the same group. Third, the model is flexible and can accommodate unbalanced data, where the number of observations varies across groups. However, there are also some limitations to consider when using random-effects GLS regression. The model assumes that the random effects are uncorrelated with the independent variables, which may not always be the case in practice. Additionally, the model requires a sufficient number of groups or clusters to produce reliable estimates of the random effects.

The Table 2 presents the results of a Random-effects GLS regression model, which is used to analyze the relationship between the dependent variable (K_MES) and a set of independent variables (EV_TGE, S_ILK, S_IKIEL, S_IPO, and EV_DA). The model is based on a panel dataset with 630 observations. The coefficients (Coef.) represent the estimated effect of each independent variable on the dependent variable, holding all other variables constant. For example, a one-unit increase in EV_TGE is associated with a 1.775 unit increase in K_MES, on average, ceteris paribus.

The standard errors (St.Err.) measure the precision of the estimated coefficients, with smaller values indicating more precise estimates.

The t-values and p-values are used to assess the statistical significance of the estimated coefficients. A p-value less than 0.05 (or 0.01 for a higher level of significance) indicates that the corresponding coefficient is statistically significant at the 5% (or 1%) level. In this case, all independent variables are statistically significant, with EV_TGE, S_ILK, S_IKIEL, and EV_DA significant at the 1% level, and S_IPO significant at the 5% level. The 95% confidence intervals provide a range of plausible values for the true coefficients, with a 95% probability that the true value lies within this range. For instance, the 95% confidence interval for EV_TGE is [0.411, 3.14], suggesting that the true effect of EV_TGE on K_MES is likely to fall within this range.

The overall R-squared (0.235) measures the proportion of the total variation in the dependent variable that is explained by the independent variables. The within R-squared (0.662) and between R-squared (0.172) provide additional information on the goodness of fit of the model, with the within R-squared indicating the proportion of variation within groups (e.g., cities) explained by the model, and the between R-squared indicating the proportion of variation between groups explained by the model. The chi-square statistic (1092.772) and its associated p-value (0.000) indicate that the overall model is statistically significant, suggesting that the independent variables jointly have a significant impact on the dependent variable. In summary, the Random-effects GLS regression results provide evidence of a significant relationship between the dependent variable (K_MES) and the independent variables (EV_TGE, S_ILK, S_IKIEL, S_IPO, and EV_DA), with all coefficients being statistically significant and the overall model having a good fit to the data.

Table 2 The Random-effects GLS Regression Full Model

K_MES	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EV_TGE	1.775	.696	2.55	.011	.411	3.14	**
S_ILK	.003	.001	4.28	0	.002	.004	***
S_IKIEL	.001	0	2.86	.004	0	.002	***
S_IPO	.001	0	2.18	.029	0	.002	**
EV_DA	25.369	1.723	14.72	0	21.991	28.747	***
Constant	272.293	69.457	3.92	0	136.16	408.427	***

Mean dependent var	575.894	SD dependent var	163.976
Overall r-squared	0.235	Number of obs	630
Chi-square	1092.772	Prob > chi2	0.000
R-squared within	0.662	R-squared between	0.172

*** p<.01, ** p<.05, * p<.1

The table 03 presents the results of a Random-effects GLS regression model, which is used to analyze the relationship between the dependent variable (K_MES) and a set of independent variables (EV_TGE, S_ILK, S_IKIEL, S_IPO, and EV_DA) using a panel dataset with 99 observations. The coefficients (Coef.) represent the estimated effect of each independent variable on the dependent variable, holding all other variables constant. For example, a one-unit increase in EV_DA is associated with a 14.065 unit increase in K_MES, on average, ceteris paribus. The standard errors (St.Err.) measure the precision of the estimated coefficients.

The t-values and p-values are used to assess the statistical significance of the estimated coefficients. In this case, only EV_DA and the constant term are statistically significant at the 5% level (p-value < 0.05), as indicated by the asterisks (**) in the "Sig" column. The other independent variables (EV_TGE, S_ILK, S_IKIEL, and S_IPO) are not statistically significant at conventional levels. The 95% confidence intervals provide a range of plausible values for the true coefficients. For EV_DA, the 95% confidence interval is [1.334, 26.796], suggesting that the true effect of EV_DA on K_MES is likely to fall within this range. The overall R-squared (0.187) measures the proportion of the total variation in the dependent variable that is explained by the independent variables. The within R-squared (0.603) and between R-squared (0.064) provide additional information on the goodness of fit of the model. The chi-square statistic (124.086) and its associated p-value (0.000) indicate that the overall model is statistically significant, suggesting that the independent variables jointly have a significant impact on the dependent variable.Compared to the previous table, the results in this table are less conclusive, with fewer statistically significant coefficients and lower R-squared values. This suggests that the model may not fit the data as well as the previous one, and that there may be other important factors affecting K_MES that are not captured by the current set of independent variables. In summary, the Random-effects GLS regression results provide evidence of a significant relationship between the dependent variable (K_MES) and the independent variable EV_DA, but the other independent variables are not statistically significant in this model. The overall model is statistically significant, but the goodness of fit is lower compared to the previous table.

Table 3 The Random-effects GLS Regression Restricted Model

K_MES	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
EV_TGE	-2.589	2.437	-1.06	.288	-7.366	2.188	
S_ILK	.006	.004	1.60	.109	-.001	.013	
S_IKIEL	.005	.003	1.48	.14	-.002	.011	
S_IPO	.007	.005	1.30	.192	-.003	.017	
EV_DA	14.065	6.496	2.17	.03	1.334	26.796	**
Constant	598.67	239.573	2.50	.012	129.116	1068.223	**

Mean dependent var	543.677	SD dependent var	141.800
Overall r-squared	0.187	Number of obs	99
Chi-square	124.086	Prob > chi2	0.000
R-squared within	0.603	R-squared between	0.064

*** p<.01, ** p<.05, * p<.1

The Table 4 presents the results of a GLS regression model with AR(1) disturbances, which is used to analyze the relationship between the dependent variable (K_MES) and a set of independent variables (N_TOP, EV_TGE, EV_DA, S_ILK, S_IKIEL, and S_IPO) using a panel dataset with 630 observations.

The AR(1) specification assumes that the error terms are correlated over time, following a first-order autoregressive process. This means that the current period's error term is influenced by the previous period's error term, capturing the persistence of unobserved factors that affect the dependent variable. The coefficients (Coef.) represent the estimated effect of each independent variable on the dependent variable, holding all other variables constant. For example, a one-unit increase in EV_TGE is associated with a 1.801 unit increase in K_MES, on average, ceteris paribus. The standard errors (St.Err.) measure the precision of the estimated coefficients.

The t-values and p-values are used to assess the statistical significance of the estimated coefficients. In this case, all independent variables except N_TOP are statistically significant at conventional levels (p-value < 0.05 or 0.01), as indicated by the asterisks (** or ***) in the "Sig" column. The coefficient for N_TOP is not statistically significant, suggesting that it does not have a significant impact on K_MES after accounting for the other independent variables and the AR(1) error structure.

The 95% confidence intervals provide a range of plausible values for the true coefficients. For example, the 95% confidence interval for EV_TGE is [0.599, 3.003], suggesting that the true effect of EV_TGE on K_MES is likely to fall within this range. The overall R-squared (0.279) measures the proportion of the total variation in the dependent variable that is explained by the independent variables. The within R-squared (0.661) and between R-squared (0.224) provide additional information on the goodness of fit of the model.

The chi-square statistic (708.717) and its associated p-value (0.000) indicate that the overall model is statistically significant, suggesting that the independent variables jointly have a significant impact on the dependent variable. Compared to the previous tables, this model includes the additional independent variable N_TOP and accounts for the AR(1) error structure. The results suggest that most of the independent variables have a significant impact on K_MES, even after controlling for the persistence of unobserved factors through the AR(1) specification. However, the coefficient for N_TOP is not statistically significant, indicating that it may not be a crucial determinant of K_MES in this model. In summary, the GLS regression with AR(1) disturbances provides evidence of significant relationships between the dependent variable (K_MES) and most of the independent variables (EV_TGE, EV_DA, S_ILK, S_IKIEL, and S_IPO), while accounting for the persistence of unobserved factors over time. The overall model is statistically significant and has a moderate goodness of fit.

Table 4 The GLS Regression Model with AR(1) Disturbances Full Model

K_MES	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
N_TOP	0	0	-1.34	.18	0	0	
EV_TGE	1.801	.613	2.94	.003	.599	3.003	***
EV_DA	24.426	1.591	15.36	0	21.309	27.544	***
S_ILK	.003	.001	3.15	.002	.001	.005	***
S_IKIEL	.002	.001	2.37	.018	0	.003	**
S_IPO	.001	0	2.06	.04	0	.002	**
Constant	283.558	61.749	4.59	0	162.532	404.584	***

Mean dependent var	575.894	SD dependent var	163.976
Overall r-squared	0.279	Number of obs	630
Chi-square	708.717	Prob > chi2	0.000
R-squared within	0.661	R-squared between	0.224

*** p<.01, ** p<.05, * p<.1

The table 5 presents the results of a GLS regression model with AR(1) disturbances, which is used to analyze the relationship between the dependent variable (K_MES) and a set of independent variables (N_TOP, EV_TGE, EV_DA, S_ILK, S_IKIEL, and S_IPO) using a panel dataset with 99 observations.

The AR(1) specification assumes that the error terms are correlated over time, following a first-order autoregressive process. This means that the current period's error term is influenced by the previous period's error term, capturing the persistence of unobserved factors that affect the dependent variable. The coefficients (Coef.) represent the estimated effect of each independent variable on the dependent variable, holding all other variables constant. For example, a one-unit increase in EV_DA is associated with a 14.757 unit increase in K_MES, on average, ceteris paribus. The standard errors (St.Err.) measure the precision of the estimated coefficients.

The t-values and p-values are used to assess the statistical significance of the estimated coefficients. In this case, only EV_DA and the constant term are statistically significant at the 5% level (p-value < 0.05), as indicated by the asterisks (**) in the "Sig" column. The other independent variables (N_TOP, EV_TGE, S_ILK, S_IKIEL, and S_IPO) are not statistically significant at conventional levels, suggesting that they do not have a significant impact on K_MES after accounting for the other independent variables and the AR(1) error structure.

The 95% confidence intervals provide a range of plausible values for the true coefficients. For example, the 95% confidence interval for EV_DA is [1.361, 28.153], suggesting that the true effect of EV_DA on K_MES is likely to fall within this range. The overall R-squared (0.197) measures the proportion of the total variation in the dependent variable that is explained by the independent variables. The within R-squared (0.601) and between R-squared (0.066) provide additional information on the goodness of fit of the model.

The chi-square statistic (109.336) and its associated p-value (0.000) indicate that the overall model is statistically significant, suggesting that the independent variables jointly have a significant impact on the dependent variable. Compared to the previous table (summary 3), this model yields different results. While EV_DA remains statistically significant, the other independent variables that were significant in the previous model (EV_TGE, S_ILK, S_IKIEL, and S_IPO) are no longer significant in this model. This difference could be due to the smaller sample size (99 observations compared to 630 in the previous model) or differences in the sample composition. In summary, the GLS regression with AR(1) disturbances provides evidence of a significant relationship between the dependent variable (K_MES) and the independent variable EV_DA, while accounting for the persistence of unobserved factors over time. However, the other independent variables are not statistically significant in this model. The overall model is statistically significant, but the goodness of fit is lower compared to the previous table (summary 3). These results highlight the importance of considering sample size and composition when interpreting regression results and the potential for different models to yield varying conclusions.

Table 5 GLS Regression Model with AR(1) Disturbances Restricted Model

K_MES	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
N_TOP	0	0	-0.10	.92	0	0	
EV_TGE	-2.505	2.559	-0.98	.328	-7.521	2.511	
EV_DA	14.757	6.835	2.16	.031	1.361	28.153	**
S_ILK	.005	.004	1.21	.227	-.003	.013	
S_IKIEL	.004	.004	1.17	.242	-.003	.012	
S_IPO	.007	.005	1.34	.179	-.003	.018	
Constant	603.134	252.763	2.39	.017	107.728	1098.541	**

Mean dependent var	543.677	SD dependent var	141.800
Overall r-squared	0.197	Number of obs	99
Chi-square	109.336	Prob > chi2	0.000
R-squared within	0.601	R-squared between	0.066

*** p<.01, ** p<.05, * p<.1

The provided tables present the results of four different regression models analyzing the relationship between the dependent variable K_MES and various independent variables. The models differ in terms of the included independent variables, sample size, and the estimation method used.

Table 1 and Table 3 use a Random-effects GLS regression model with a larger sample size of 630 observations. In both models, most of the independent variables (EV_TGE, S_ILK, S_IKIEL, S_IPO, and EV_DA) are statistically significant at conventional levels, with EV_DA having the largest coefficient. The overall R-squared values are 0.235 and 0.279, respectively, indicating that the independent variables explain a moderate proportion of the variation in K_MES. The chi-square statistics and their associated p-values suggest that both models are statistically significant overall.

Model Table 2 and Table 4 use a smaller sample size of 99 observations. Table 2 employs a Random-effects GLS regression model, while Summary 4 uses a GLS regression with AR(1) disturbances. In both models, only EV_DA and the constant term are statistically significant at the 5% level, while the other independent variables are not significant. The overall R-squared values are lower compared to Model Table 1 and Table 3, at 0.187 and 0.197, respectively. Despite the lower goodness of fit, the chi-square statistics and their associated p-values indicate that both models are statistically significant overall.

The differences in the results between the models with larger and smaller sample sizes suggest that sample size and composition can influence the significance of the independent variables and the overall goodness of fit. The inclusion of the N_TOP variable in Model Table 3 and Table 4 does not appear to have a significant impact on K_MES, as its coefficient is not statistically significant in either model. In conclusion, the four regression models provide evidence of a significant relationship between K_MES and some of the independent variables, particularly EV_DA, which remains statistically significant across all models. However, the significance of the other independent variables varies depending on the sample size and the estimation method used. The models with larger sample sizes generally exhibit better goodness of fit and more statistically significant independent variables compared to the models with smaller sample sizes.

4. Discussion

The findings from the regression analyses presented in the four summary tables provide valuable insights into the factors influencing the housing market in Türkiye, as measured by the dependent variable K_MES. The results highlight the importance of various independent variables, such as EV_TGE, S_ILK, S_IKIEL, S_IPO, and EV_DA, in explaining the variation in K_MES. However, the significance of these variables varies across the models, depending on the sample size and the estimation method employed.

The discussion document sheds light on the recent trends and challenges faced by the Turkish housing market over the past decade. The first half of this period was characterized by a balance between increasing housing production and stable prices, indicating a healthy and growing market. However, the latter five years witnessed a decline in housing supply, rising costs, and the impact of macroeconomic regulations, which have adversely affected the market. The regression results from Model Table 1 and Table 3, which use a larger sample size of 630 observations, provide evidence of the significant impact of most independent variables on K_MES. The variable EV_DA, which represents the "Economic Value of Developed Areas," has the largest coefficient and is statistically significant at the 1% level in both models. This finding suggests that the development of urban areas plays a crucial role in determining housing market outcomes. The positive and significant coefficients of S_ILK, S_IKIEL, and S_IPO indicate that factors such as "Number of Residences," "Number of Workplaces," and "Number of Offices" also contribute to the growth of the housing market.

However, the discussion document highlights the challenges faced by the housing market in the latter five years, particularly the decline in housing production and the impact of inflation and the depreciation of the Turkish Lira. These challenges have led to substantial losses for housing investors and have driven up housing prices while suppressing demand. The regression results from Model Table 2 and Table 4, which use a smaller sample size of 99 observations, reflect these challenges. In these models, only EV_DA and the constant term remain statistically significant, while the other independent variables lose their significance. This finding suggests that the impact of the other factors on the housing market may have diminished in the face of the economic challenges experienced in recent years. The discussion document also points out the diverging trends between the construction and real estate sectors after 2017. While construction activities declined, real estate activities continued to thrive, indicating a potential disparity in the market. The document suggests that attempts to hide this disparity in the face of rising inflation may have worsened the problem. The increasing unit costs of undeveloped properties have pushed investors towards individual and speculative land investments, highlighting the lack of regulatory support for production and housing needs through rental solutions in previous periods.

To address these housing market challenges, the discussion document emphasizes the need for proactive measures to boost housing production and reconsider housing as an investment option. The regression results support this view, as they demonstrate the significant impact of factors such as EV_DA and S_ILK on the housing market. Policymakers and market participants should focus on incentivizing and supporting sustainable housing production to ensure a stable and healthy market. Furthermore, the discussion document stresses the importance of making housing more accessible and affordable, reducing its appeal as a purely speculative investment. This recommendation aligns with the regression results, which highlight the significance of variables such as S_IKIEL and S_IPO in explaining housing market outcomes. By implementing measures to promote affordability and accessibility, policymakers can help create a more balanced housing market that serves the needs of both investors and individuals seeking sustainable quality housing in Türkiye.

In conclusion, the regression analyses and the discussion document provide a comprehensive understanding of the factors influencing the Turkish housing market and the challenges it has faced in recent years. The findings emphasize the need for proactive measures to support sustainable housing production, promote affordability and accessibility, and address the diverging trends between the construction and real estate sectors. By considering the insights from both the quantitative analyses and the qualitative discussion, policymakers and market participants can work towards creating a more stable, balanced, and sustainable housing market in Türkiye.

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Notes

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Maral Taşcılar is a young professional specializing in real estate development and strategic consultancy. She holds a Bachelor of Architecture and a Master of Science degree in Real Estate Development, both from Istanbul Technical University. Maral currently serves as the Senior Development Executive at HAN Spaces, a leading flex office provider based in Turkey. In this role, she oversees the planning and execution of all national and international expansion projects, contributing to the company's growth and positioning in the dynamic flex office market. Prior to joining HAN Spaces, Maral gained valuable experience at JLL's Valuation & Strategic Consultancy department. Her professional and academic pursuits focus on the intersection of real estate and technology. She is the author of scientific contributions on new technologies in real estate research, exploring the transformative impact of big data on commercial property forecasting, offering new perspectives on data-driven methodologies and market-oriented real estate analysis.

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Maide Dönmez is an undergraduate student in Urban and Regional Planning at Istanbul Technical University. She has a strong academic interest in sustainable urbanization, digital transformation, remote sensing, and mapping. Throughout her studies, Maide has conducted research on various topics, including energy modeling in post-disaster settlements, resilient urbanization, and urban segregation. Currently, her *work focuses on exploring innovative approaches to urban planning, with an emphasis on social equity, sustainability, and resilience. She aims to develop solutions that integrate these principles to create more inclusive and adaptable urban spaces, improving the quality of life and ensuring long-term sustainability for future generations.*

Belinay Hira Güney continues her undergraduate education at Istanbul Technical University, Department of Urban and Regional Planning and double majoring in Architecture. She is interested in urban design, data visualization, participation in planning and artificial intelligence and aims to develop herself in these disciplines. During her studies, she has worked on various topics such as sustainable urbanization, integration of digital technologies into urban planning and energy modeling in post-disaster settlements. She is currently focusing her research on the sharing economy, social media content and urban quality of life, aiming to contribute to the development of innovative solutions for the cities of the future.

Şule Tağtekin is currently an undergraduate student of urban and regional planning at Istanbul Technical University. She is interested in research and development studies conducted in the application of geographic information systems. In these studies, she is interested in both technical analysis production, visualization, and sociological evaluation of these studies and what the effects of these studies will be and how solutions will be provided. This study is about the energy demand model that emerges after a disaster, and she aims to look at studies with different outputs from a multi-faceted perspective and develop innovative suggestions.

Candan Bodur is an undergraduate student at Istanbul Technical University, Department of Urban and Regional Planning. She focuses on research and development in geographic information systems (GIS) applications, with a particular interest in technical analysis and visualization evaluation of these studies. Throughout her studies, she explores the potential impacts of GIS studies, aiming to provide effective solutions to contribute to urban planning by establishing a link between the physical and digital world, through simulations, analysis and forecasting. Currently, her work aims to analyze different outputs from a multidimensional perspective and develop innovative recommendations by studying post-disaster energy demand patterns.

Yulia Beşik continues her undergraduate education at Istanbul Technical University, Department of Urban and Regional Planning with minoring in Economics. She is interested in regional planning, data visualization, and urban design and aims to further develop herself in these areas. During her studies, she has worked on various subjects such as energy modeling in post-disaster settlements, digitalization process of regions, development of a eco-town. Currently she is focusing on creative cities, sustainable urbanisation and urban quality of life, aiming to develop solutions for cities' future.