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Estimation and analysis of substitution elasticity between land and capital inputs in housing production in Khorramabad City and its impact on urban development*

Case Study

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Abstract

The unique characteristics of housing—alongside the essential need for shelter and its distinctive position in the macroeconomy—have made it one of the most critical productive goods in any economy. Therefore, understanding how housing production inputs, particularly land and capital, are utilized, as well as recognizing developers' responses to relative changes in input prices, is of considerable importance. The elasticity of substitution between land and capital is an indicator that reflects producers' flexibility when faced with changes in input prices. The present study was conducted with the aim of estimating the elasticity of substitution between land and capital inputs in housing production in the city of Khorramabad. The research methodology is descriptive-analytical, and the study is applied in nature. The statistical population included 110 urban blocks within Khorramabad, which, after the review, were reduced to 100 blocks. The data were collected in 2025 through field surveys applying a stratified sampling method. The elasticity of substitution between land and capital inputs was estimated using the ordinary least squares (OLS) method for constant elasticity of substitution (CES) and variable elasticity of substitution (VES) functions at the levels of the entire city, the city center, and the urban fringe. The findings indicated that the elasticity of substitution was less than one in all estimates. This implies that in response to a relative increase in land prices, building heights (as a proxy for capital intensity) increase by a smaller percentage, and capital serves only as a limited substitute for land in housing production in Khorramabad city.

Keywords

capital input
elasticity of substitution
housing production inputs
Khorramabad city
land input

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1. Introduction

The dual nature of housing as both a consumer and capital good, along with its characteristics—such as irreplaceability in consumption, inelastic supply, heterogeneity, and low depreciation rates—has rendered housing a unique commodity (Hasanvand, 2024, p. 165). The necessity of housing as shelter and its significant share in household expenditure baskets have made housing one of the most fundamental goods produced in any country. According to a report by the Statistical Center of Iran, the share of housing costs for urban households rose from 38 percent in the year 1401 (2022–2023) to 43.7 percent in 1403 (2024–2025) (Statistical Center of Iran, 2025,p. 50). This report indicates that a considerable portion of Iranian households are compelled to overlook, to some extent, their other essential needs to cover their housing costs. Furthermore, the tenure type (owner-occupied or rental) and the geographical location of housing can affect assets, wealth, welfare, and even dimensions of social status (Gholizadeh et al., 2022, p. 107). At the macroeconomic level, the housing sector is also regarded as one of the most important economic sectors; characteristics such as extensive forward and backward linkages, high potential for job creation, significant capacity for absorbing liquidity, and a considerable share in gross fixed capital formation have transformed the housing sector into a driver of economic growth (Abbasinejad & Yari, 2009, p. 60).

The importance of housing is not limited solely to its economic dimensions. The physical development pattern of housing and the manner of its settlement in urban space have direct consequences for population distribution, spatial deprivation, and the quality of the living environment (Vasali Azarsharbyani et al., 2017, p. 3). Therefore, governments try, through attention to this sector, not only to provide adequate housing and enhance social welfare, but also to pursue their developmental and economic objectives (Manochehri & Gholizadeh, 2022, p. 186).

Based on a report published by the Statistical Center of Iran, the average sales price per square meter of land and housing in urban areas from the year 1396 (2017–2018) to 1400 (2021–2022) increased by approximately 832 and 632 percent, respectively. Moreover, the residential input price index grew by 37.1 percent in 1402 (2023–2024) and 30 percent in 1403 (2024–2025). Such instability in the housing market, in addition to increasing risk for investors, has weakened the economic capacity of the middle and low-income classes and led to a decline in their social satisfaction (Statistical Center of Iran, 2025,p 127).

These fluctuations have heightened the necessity of paying attention to the production and supply of housing, and particularly the optimal use of its production inputs. Two inputs, land and capital, are critical in housing production, with capital considered to include any input other than land (Epple et al., 2010, p. 2). These inputs are utilized in the housing production process either as complements or substitutes, and their price fluctuations and supply levels affect the production capacity of different sectors (Sobhani Sabet & Manzoor, 2014, p. 158). With a relative increase in land prices, housing producers attempt to increase building heights by using less land and injecting more capital. In this context, the elasticity of substitution between land and capital inputs is a critical parameter in the housing production function, which indicates the extent to which housing builders, in reaction to input price fluctuations, are willing to substitute capital for land. The magnitude of this indicator affects urban density and spatial structure. In regions with high elasticity of substitution, a relative increase in land prices leads to greater capital deployment, resulting in the construction of high-rise buildings, new housing supply, and increased density (Ahlfeldt & McMillen, 2014, p. 1). However, in regions with low elasticity of substitution, a relative increase in land prices does not lead to a substantial use of capital and creates little change in building heights. In such areas, land, as an input with limited substitutability, plays a decisive role in the production and final price of housing.

The special position of housing in economic and social affairs has always attracted the attention of researchers, policymakers, and economic planners. However, although numerous studies have examined various elasticities in the housing market, the elasticity of substitution between land and capital inputs in housing production has received less attention. This is despite the fact that the housing production process is heavily influenced by the manner in which land and capital inputs are combined and utilized. The limited supply of urban land is one of the main challenges in housing production, alongside rising construction costs, which have compounded the importance of investigating the substitutability of capital for land (Bayat Sarmadi, 2008, p. 13). On the other hand, examining the floor area and land area of residential buildings is essential. Without accurate statistics on construction activities, the evaluation and implementation of macro-level plans will lack the necessary precision (Yarmohamadian & Salarvand, 2020, p. 233).

In this regard, neglect of the mechanisms governing factor combination and disregard for the substitutability between land and capital can lead to the adoption of inefficient policies and the waste of resources in the housing sector. A lack of proper understanding of the housing supply response to relative changes in input prices results in inaccurate estimates of future housing price fluctuations and affects the efficiency of housing programs. Moreover, in regions with a high elasticity of substitution, urban density policymaking faces serious challenges if this indicator is disregarded. In response to rising land prices, the increased use of capital and construction of high-rise buildings can impose significant pressure on infrastructure, transportation networks, and public services, ultimately reducing the quality of urban life through excessive densification. Ultimately, applying this indicator, in addition to providing a better understanding of the behavior of housing producers and enabling the formulation of efficient policies for resource allocation, can assist planners and government officials whose primary objectives are achieving urban growth control, increasing the efficiency of public services, and attaining sustainable urban development commensurate with regional capacities.

In recent decades, Iranian cities have faced population growth and physical expansion. Factors such as natural population growth, increased rural-to-urban migration, the transformation of household structures from extended to nuclear families, and the concentration of commercial, service, and welfare activities in cities have increased the demand for urban housing. This growth in demand has caused cities to expand into surrounding lands. The city of Khorramabad, as one of the central cities of the country, has not been exempt from these transformations. However, due to the city's specific natural structure and topography—including its location in a valley and being enclosed by mountains—the supply of land has been limited, and the possibility of horizontal expansion of the city has encountered difficulties (Saraei et al., 2014, pp. 51-53). Increased competition for the acquisition of urban land, alongside influential macroeconomic factors, has exerted upward pressure on housing prices, which in turn has led to higher land prices. With the increase in land prices, the land input in housing production becomes more expensive; as a result of optimization, housing producers substitute capital for land, leading to the construction of taller buildings. The present study aims to estimate the elasticity of substitution between land and capital inputs in the city of Khorramabad and to demonstrate the rate at which the increase in building heights occurs in response to a relative increase in land prices. The distinguishing feature of this study compared to most previous research is the simultaneous application of two production functions—CES and VES—which provides the possibility of a more precise and realistic assessment of the degree of capital substitution for land. Furthermore, the manner of factor combination is examined not only for the entire city but also disaggregated for the city center and periphery, enabling a comparison of spatial differences in the substitutability of production factors across different parts of the city.

2. Theoretical foundations

2.1. Elasticities in the housing market

Elasticity is one of the fundamental concepts in economic analysis, measuring the sensitivity of one variable to changes in another. This concept plays a significant role in analyzing the behavior of consumers and producers in various markets. It helps economists examine how economic agents react to changes in prices, income, and other economic variables. In the housing market, due to the specific characteristics of this market, the analysis of elasticities assumes particular importance. The housing market is recognized for features such as the heterogeneity of residential units, the limited supply of urban land, the time-consuming nature of the construction process, and strong susceptibility to locational conditions. For this reason, examining various types of elasticities can provide a more precise understanding of the functioning of this market and the behavior of housing suppliers and demanders.

In the housing economics literature, various types of elasticities have been considered, among the most important of which are the price elasticity of housing supply, the price elasticity of housing demand, the income elasticity of demand, the cross-price elasticity of demand, and the elasticity of substitution of production inputs. Each of these indicators explains different dimensions of housing market behavior and, collectively, provides an analytical framework for examining the economic mechanisms governing this market.

The price elasticity of housing supply indicates the extent to which suppliers react to changes in housing prices. If the supply elasticity is high, an increase in housing prices will lead to a significant increase in construction and the supply of new residential units. In such conditions, the market moves toward equilibrium through increased production. Conversely, in conditions where the supply elasticity is low, housing supply cannot rapidly respond to increased demand, and consequently, a significant portion of market adjustment occurs through price increases (Dehgan Tezerjani et al., 2021, p. 123). Limitations of urban land, urban planning regulations, construction costs, and the lengthy housing production period are among the factors that can reduce the supply elasticity in the housing market.

Alongside the supply, the price elasticity of housing demand is also one of the important indicators in analyzing market behavior. This elasticity shows the sensitivity of housing demanders to price changes. Since housing is considered one of the basic needs of households, in many cases, its price elasticity of demand is relatively low, meaning that even in the event of price increases, households still need to secure shelter. However, in some market segments, especially in conditions where capital demand in the housing market increases, the sensitivity of demand to price changes can increase (Manochehri et al., 2024, p. 189).

The income elasticity of housing demand is also applied to examine the relationship between household income and housing demand. This indicator shows the extent to which households' housing demand increases with rising incomes. If the income elasticity is greater than one, housing is considered a luxury good, and an increase in income will lead to a more-than-proportionate increase in its demand (Brzezicka & Kobylińska, 2021, p. 123). Conversely, if the income elasticity lies between zero and one, housing is classified in the category of necessary goods, and an increase in income will only lead to a limited increase in demand (Basri et al., 2021, p. 98).

The relationship of the housing market with other assets and goods can be analyzed through the cross-price elasticity of housing demand. This indicator expresses the extent to which changes in the prices of other goods or assets can affect housing demand. In the consumption dimension, housing may have a complementary relationship with certain goods, such as home appliances, meaning that a change in the price of those goods can affect housing demand. In the capital dimension, housing can also serve as one of the investment assets alongside assets such as gold, currency, and stocks. In such conditions, changes in the prices of these assets may influence the level of investment in the housing market (Aleemran & Aleemran, 2023, p. 449).

Despite the importance of various elasticities in analyzing the housing market, one of the fundamental topics in urban economics and housing economics concerns the examination of the relationship between housing production inputs. Housing production, like many other economic activities, requires the use of factors of production, the most important of which are land and building capital. Land, as a limited and immobile input, plays a decisive role in the spatial structure of cities and housing prices. In contrast, building capital includes construction materials, labor, equipment, and other inputs utilized in the construction process.

In this framework, the concept of the elasticity of substitution between production inputs assumes particular importance. Cities tend to expand as they grow and become wealthier. Consequently, with the increase in demand for housing, construction activities also increase, affecting the prices of production factors. Under these conditions, one of the key questions in housing economics is the extent to which it is possible to substitute one input for another in the event of a price change or supply limitation of one of the inputs. This issue is explained through the concept of the elasticity of input substitution. The elasticity of substitution was introduced by Hicks in 1932 (Stern, 2011, p. 2). The elasticity of substitution between land and capital indicates the extent to which a relative increase in land prices drives builders to use more capital and reduce land consumption (high-rise construction). The magnitude of this elasticity plays a decisive role in the effectiveness of land policies, urban regulations, financial support, and ultimately housing prices.

In cities where there is a high elasticity of substitution, land will have the greatest impact on housing prices, and housing builders attempt to make greater use of land through vertical construction. In such areas, municipalities can, by imposing regulations, adjust density in accordance with the infrastructural capacity of the region. Governments can also, through financial and credit support for builders, manage housing prices in the face of demand-side shocks. As builders have high flexibility to substitute capital for land, and with the provision of adequate financial resources, the possibility of greater housing supply is enabled

(Batisani & Yarnal, 2011, p. 77). In cities where land supply is also limited, imposing taxes on land and its transactions somewhat reduces land use (Erol & Güzel, 2006,p. 97). Moreover, high elasticity of substitution in some cases leads to economic growth, because the greater use of capital, due to its linkages with other fields of economic activity, will result in increased per capita income and economic growth (Chilarescu, 2025, p. 1).

In regions with low elasticity of substitution, capital will be a poor substitute for land, and there will be a tendency toward horizontal development in the city. If households have strong preferences for large residential land plots, governments can influence housing prices through land liberalization, reducing taxes on land, or granting subsidies to land prices in certain areas (Batisani & Yarnal, 2011, p. 77). In such regions, if they face limited land supply, an increase in land prices will have a strong effect on housing prices, and housing supply is also typically less flexible (Paciorek, 2013,p. 36).

2.2. Analysis of housing producers' behavior

The conventional model of the housing production function, which underlies almost all theoretical models in urban and local economics, assumes that housing can be considered a homogeneous and divisible good, denoted by Q. This model considers the supply and demand of housing as continuous quantities of the flow of housing services. In the basic model, housing is produced from two factors: capital. (K) and land (L), applying the function Q=f(L,K). In fact, capital (K) is considered a combination of non-land and mobile factors that is constant across all locations within an urban area. Logically, the price of land depends on its geographical location. Since housing is immobile, its price is also dependent on the location of the land. It is also assumed that the housing industry and inputs operate in a perfectly competitive market (Epple et al., 2010, p. 5).

Within the framework of the theory of producer behavior, the revenue of a housing builder is calculated from the product of the selling price per square meter of built floor area multiplied by the total floor area produced. Production costs also include the two main inputs of land and capital. In this context, the cost of using each square meter of land is denoted by the symbol r and serves as the price of the land input. The symbol n also expresses the cost per unit of capital. Therefore, the total cost of building production is represented as follows:

$$C=nK+rL \qquad (1)$$

Although n is constant across different locations, r must vary in such a way that housing producers in different parts of the city have varying incentives for construction. The reason is that in locations close to the city center, due to the high price of land and consequently the higher price per square meter of produced space, there is a greater return for builders compared to land on the city periphery.

This theory can be explained using isoquant curves and least-cost analysis. For this purpose, a diagram is employed in which the capital input is on the vertical axis and the land input is on the horizontal axis. The isoquant curves represent different combinations of land and capital that all result in the production of a constant quantity of residential space. The optimal point for each producer is, in fact, the point where the slopes of the cost line and the isoquant curve are equal.

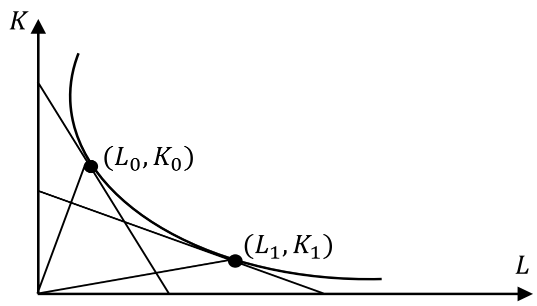

Figure 1. Optimization behavior of housing producers (Shakarmi, 2018,p. 27)

Assuming that the city resembles a concentric circle, the behavior of producers in different parts of the city can be examined. In the city center, where the cost of using each square meter of land equals $r=r_0$, the cost of land use is high, and the iso-cost lines are steeper, with their slope equal to $\frac{r_0}{n}$. Under such conditions, to produce a specific level of residential space, Q , the producer is compelled to reduce land consumption and employ more capital instead. The result of such a choice is the construction of taller buildings. This combination is shown as (L_0,K_0) in Figure 1.

In contrast, in peripheral areas where the cost of land use is lower, where $r = r_1$ and $r_1 < r_0$—producers face cost lines with a gentler slope ($\frac{r_1}{n}$). In such a location, the optimal combination of inputs for producing the same level of residential space will include greater land consumption and less capital compared to the city center. For this reason, buildings on the city periphery are mostly constructed as low-rise structures. This combination is shown as (L_1,K_1) in Figure 1.

This behavioral difference is reflected in the capital-to-land ratio. The ratios $\frac{K_0}{L_0}$ and $\frac{K_1}{L_1}$, which respectively represent the optimal input combinations in the city center and the city periphery, indicate that buildings in the city center have greater heights compared to those on the periphery. However, the intensity and pattern of this characteristic depend on the housing production function and the input price ratio. ($\frac{r}{n}$). In this context, the elasticity of substitution between land and capital is considered a suitable tool for measuring the behavior of producers in altering the input combination. The elasticity of substitution indicates the way the input ratio changes when moving along an isoquant curve. The greater the curvature of the isoquant curve, the more limited the substitutability between inputs and the lower the elasticity (Yarmohamadian & Salarvand, 2020, pp. 235-236; Shakarmi, 2018, pp. 19-28).

3. Empirical background

3.1. Domestic studies

Maleki et al. (2026) conducted a study entitled "Identifying Key Factors Affecting Housing Prices with a Futures Studies Approach: A Case Study of the City of Khorramabad." Applying analysis of data obtained from the Delphi method and cross-impact analysis, they concluded that factors such as household income, land prices, building density, number of units and floors, access to urban facilities and services, population density, geographical location of lands, future non-residential uses, number of rooms, security status, size of property parcels, and demand conditions play a role as the main factors influencing housing prices in the city of Khorramabad (Maleki et al., 2026).

Piri et al. (2023), in a study entitled "A Model of Housing Investment with a Parallel Markets Approach," showed that the elasticity of housing investment with respect to the exchange rate and the stock price index is 28 percent and -21 percent, respectively. The gold coin price index and the bank interest rate also affect residential investment by 0.11 and 0.9 percent, respectively. The results of this research generally indicate that developments influence investment in the housing sector in parallel markets, and changes in the currency, gold, and capital markets, as well as the bank interest rate, can redirect capital flows in the housing sector (Piri et al., 2023).

Heydari et al. (2022) evaluated the impact of speculative behavior of banks on housing prices in the districts of Tehran using a panel data model for the period 1392 to 1398 (2013–2019). The results of their study showed that the speculative performance of non-governmental banks has a far greater effect on housing prices than that of governmental banks. The elasticity of housing prices with respect to surplus deposits in privatized and private banks had the highest coefficient, and the highest elasticity of housing prices with respect to bank debt to the Central Bank was observed in specialized banks. The price elasticity of housing with respect to non-current loans in commercial and specialized banks also ranked highest (Heydari et al., 2022).

Sameti et al. (2022), in a study using data from urban households across the country during the years 1376 to 1396 (1997–2017) and employing the linear expenditure system(LES) and the seemingly unrelated regression(SUR) econometric technique, estimated the income elasticity for the food, beverage, and tobacco group and the housing, water, electricity, and other fuels group to be less than one, equivalent to 0.95. This result indicates that these groups have an essential nature in the household consumption basket, and as income increases, their expenditure share increases to a proportionally lesser extent (Sameti et al., 2022).

Yarmohamadian and Salarvand (2020), in a study calculating the elasticity of substitution between land and capital in housing production in the city of Dorud in the year 1397 (2018–2019), applying VES production functions, estimated it to be greater than one. This finding demonstrated that there is a relatively high possibility of substitution between land and capital inputs in housing production in the city of Dorud, and builders can, to some extent, respond to relative changes in input prices by altering the combination of these inputs (Yarmohamadian & Salarvand, 2020).

Shabanpour et al. (2019), in a study, examined the factors affecting housing prices in the city of Rasht using t-tests and the Friedman test. The results of their research indicate that factors such as land prices, inflation, municipal charges, construction service costs, geographical location, possessing title deeds, and property parcel size have little effect on housing prices, despite the factor of access to services, which has a moderate effect on housing prices (Shabanpour et al., 2019).

Morovat et al. (2018), in a study, investigated the factors affecting the supply of new housing and estimated the price elasticity of new housing supply in Iran using provincial data for the period 1379–1392 (2000–2013). They estimated the housing supply and demand functions using the econometric method of simultaneous equations and panel data. Also, due to the dynamic nature of the demand equations, the generalized method of moments (GMM) was applied for parameter estimation. The findings of their study indicated that the price elasticity of housing supply in the short term and medium term is 0.25 and 0.5, respectively; therefore, due to the low elasticity of housing supply, demand-side shocks lead to significant price increases in the housing sector (Morovat et al., 2018).

Shakarmi (2018), in his thesis, calculated the elasticity of substitution between the two inputs of land and capital in housing production in the city of Ilam using a translog model to be equal to 0.71. He also concluded that in the geographically weighted regression model, the elasticity of substitution is influenced by several variables that have a positive effect on the logarithm of the land input relative to capital. The logarithm of the capital input has a negative effect on the deflated value of capital, which was deflated using the price index (Shakarmi, 2018).

Khoshakhlagh et al. (2016), in a study entitled “Estimating the Housing Supply Function in Cities and Villages of Isfahan Province (1991–2011),” using the Lucas supply approach and incorporating adjustment costs, concluded that housing supply has low elasticity with respect to wages, credit supply, and housing prices. This finding indicated that housing supply has limited flexibility in the short term, and changes in these variables do not strongly affect housing supply (Khoshakhlagh et al., 2016).

Khouzani Amini et al. (2016), in a study, examined consumption and investment housing demand in Iran during the period 1374–1392 (1995–2013). In the consumption approach, the behavior of urban household deciles in the country was examined using panel data, the LES model, and SUR. In the investment approach, the effects of variables such as housing prices, household income, gold prices, the consumer goods price index, and housing credits were also evaluated. The research findings showed that in the consumption approach, the income elasticity of housing demand is -0.81; also, the negativity of the cross-price elasticity of the commodity groups indicates their complementarity with housing in the household consumption basket. The results of the investment approach also indicated the positivity of the cross-price elasticity of housing demand with respect to changes in the price of other assets (Khouzani Amini et al., 2016).

Arman et al. (2015), using the dynamic linear ideal demand system and the SUR method, evaluated the demand function and elasticity of consumer goods among low-income and high-income groups in urban areas during the period 1361–1386 (1982–2007). The results of their income elasticity calculation showed that in low-income groups, the food and housing groups are essential, and the miscellaneous and clothing groups are luxuries. Meanwhile, for the high-income group, the health, recreation, and education group is more essential than other goods, followed by the three groups of food, clothing, and housing, with the miscellaneous group being a luxury (Arman et al., 2015).

Salarzehi et al. (2014) conducted research aimed at providing a comprehensive understanding of the consumption pattern of Iranian households and identifying consumption sensitivities to price changes across commodity groups, using data on urban household budgets in the country (1974–2007). The results of their research indicated that the highest degree of Allen elasticity of substitution is between the transportation and housing groups, and based on expenditure elasticity, the food and housing commodity groups are recognized as two essential commodity groups, while the clothing, furniture and furnishings, health and medical care, and transportation groups are recognized as luxury commodity groups (Salarzehi et al., 2014).

Rahdari and Leylian (2012), in a study for the city of Kerman, estimated the housing demand function using the hedonic price model for the period 1378–1388 (1999–2009). By examining the housing demand function, they concluded that the income elasticity of demand for floor area and central heating systems is positive, and the income elasticity of distance from the city center is negative. In their study, they also obtained a price elasticity greater than one (Rahdari & Leylian, 2012).

Bayat Sarmadi (2008), in his thesis, calculated the elasticity of substitution between land and non-land inputs across cities in the country using the OLS method for the years 1373 (1994–1995) and 1378 (1999–2000) to be 0.691 and 0.692, respectively. The results of this study indicate that the degree of substitution between the land input and non-land inputs is less than one, and land, as one of the determining factors in the housing production process, continues to be considered an input with limited substitutability (Bayat Sarmadi, 2008).

Ghaderi (2003), in a study using 12,338 urban household samples employing the OLS method in the year 1380 (2001–2002), calculated the income elasticity of demand for owner-occupied and rental housing to be less than one (Ghaderi, 2003).

3.2. Foreign studies

Vikkelsø (2024), in a study for Denmark, first modeled housing production using the CES production function, then, using data from 7,661 properties and employing the nonlinear least squares method, estimated the average elasticity of substitution between land and non-land inputs for the period 2010 to 2021 to be greater than one, equivalent to 1.143. This finding indicated that in the Danish housing market, there exists a relatively high possibility of substitution between land and other housing production inputs (Vikkelsø, 2024).

Zhang et al. (2022), focusing on the city of Xi'an in China and using land transaction and housing market data from 2018, estimated the elasticity of substitution between land and capital within the CES function framework to be equal to 0.6611. Furthermore, this elasticity was observed to be higher in the central areas of the city and lower in the peripheries, indicating the heterogeneity of the urban development structure and differing spatial constraints in various parts of the city (Zhang et al., 2022).

Combes et al. (2021), relying on 218,657 observations from the French housing market, estimated the housing production function. Their findings indicated that the elasticity of substitution between land and capital is significantly less than one, and perfect substitution between these two inputs is not possible (Combes et al., 2021).

Brzezicka and Kobylinska (2021) estimated the income elasticity of housing demand to be greater than one and considered housing a luxury good for Polish citizens (Brzezicka & Kobylinska, 2021).

Arbel et al. (2018), using data from newly constructed single-family residential units during the years 1996 and 1997 across the United States and applying the CES function, concluded that with a one-degree Fahrenheit increase in temperature, the elasticity of substitution between land and structure increases between 0.0149 and 0.0203. Their findings showed that climatic conditions can also affect the manner in which production factors are combined in housing construction (Arbel et al., 2018).

Ahlfeldt and McMillen (2018), in a study for the city of Chicago over the period 1870 to 2010, estimated elasticities related to building height, construction costs, and the substitution of land and capital. They showed that the elasticity of substitution for 30-story commercial buildings was approximately 0.76, and for residential buildings, depending on the OLS and IV estimation methods, it varied between 0.47 and 0.6 (Ahlfeldt & McMillen, 2018).

Albouy and Ehrlich (2018), in research focusing on housing productivity and the social costs of land use restrictions, concluded that in cities with severe land use restrictions, the possibility of substitution between housing production inputs decreases and the cost of housing production increases (Albouy & Ehrlich, 2018).

Ahlfeldt and McMillen (2014), using the EGS approach and data from the cities of Chicago, Berlin, and Pittsburgh, estimated the elasticity of substitution between land and capital. In their research, they attempted to reconcile the contradictory evidence regarding the elasticity of substitution between land and capital using the EGS approach. The results of their research indicated that the actual elasticity between land and capital is, in most cases, close to unity (Ahlfeldt & McMillen, 2014).

Garcia and Raya (2011) conducted a study entitled "Income and Price Elasticities of Housing Demand in the City of Barcelona." In their research, they showed that in the housing market, the floor area of a residential unit can be considered a luxury good, while the quality and location of housing fall more within the category of its essential characteristics (Garcia & Raya, 2011).

Batisani and Yarnal (2011) estimated the elasticity of substitution between land and capital in housing production in the city of Gaborone, located in Botswana, using CES and VES functions. They calculated the elasticity of substitution under the CES function for the entire city and the municipalities of districts one, two, and three to be 0.997, 0.725, 0.987, and 0.997, respectively. Also, the parameter value for the VES function for the entire city and the municipalities of districts one, two, and three were obtained as 0.85, 0.54, 0.7, and 0.72, respectively (Batisani & Yarnal, 2011).

Epple et al. (2010), focusing on new housing construction in the city of Pittsburgh, located in Allegheny County, calculated the weighted average elasticity of substitution between land and non-land inputs. The findings showed that the elasticity of substitution between land and non-land factors varies between 1 in the linear form to 1.16 in the log-linear form, indicating the relatively high flexibility of housing producers in choosing the combination of production factors (Epple et al., 2010).

Erol and Güzel (2006), in a study for the city of Ankara and relying on residential building data completed in the year 2000, obtained the elasticity of substitution between land and capital for the CES production function for the entire city and the municipalities of districts 1 and 2 to be equal to 0.078, 0.07, and 0.29, respectively. Also, the value of this parameter for the VES production function was estimated to be equal to 0.118, 0.178, and 0.34, respectively. The results of this research indicate that in the Ankara housing market, the possibility of substitution between land and capital is limited, and capital does not constitute a perfect substitute for land (Erol & Güzel, 2006).

Conder and Larson (1998), in a study, undertook the calculation of the elasticity of substitution between land and capital. Their sample size comprised 5,500 data points from the counties of Clackamas, Multnomah, and Washington. They applied three models to estimate the elasticity of substitution, in all of which the production function was assumed to be CES. The results of their research indicated that the elasticity of substitution between land and capital for models 1, 2, and 3 was obtained as 0.64, 0.8, and 0.78, respectively, indicating imperfect substitution between these two inputs (Conder & Larson, 1998).

A review of the results of domestic and foreign research shows that the degree of elasticity of substitution between land and capital inputs has varied from less than one to greater than one across different cities and does not follow a single pattern. Furthermore, no research has yet independently addressed the elasticity of substitution between land and capital inputs in housing production in the city of Khorramabad. Therefore, this study has been undertaken to fill this research gap and to provide a clear picture of the manner in which production factors are combined in response to the relative increase in input prices in the city of Khorramabad.

4. Research methodology

4.1. Study area

The city of Khorramabad, according to the 1395 (2016) census, with a population of 373,416, is located in the west of the country and in the center of Lorestan Province (Lorestan Management Organization, 2023). The gradual development of the city of Khorramabad took place with the establishment of the municipality in 1305 (1926) and the founding of a military garrison in the east of the city (LalePour et al., 2022, p. 923). This city is situated in a valley of the same name, the elevation of which ranges from about 1,100 meters to over 1,400 meters above sea level (Beiranvandzadeh et al., 2023, p. 115).

A series of Zagros Mountain heights surrounds the city of Khorramabad. In the northern and northeastern parts of the city, the slopes of Makhmalkouh, with an elevation of approximately 1,800 meters, and in the southern and southeastern parts of the city, the Madbeh and Poshteh mountains, with an elevation between 1,500 and 1,860 meters, are located. Also, Sefidkouh, the most prominent mountain near the city, located in the western part, has an elevation between 1,700 and 2,000 meters above sea level. Consequently, the mountains surrounding the city are higher than the floor of the Khorramabad Valley and naturally enclose the city.

The expansion of the city has taken place in accordance with the shape of the valley and the slope of the land. The valley is approximately 15 kilometers long and 10 kilometers wide and generally has a gentle slope from north to south. In areas where the valley is wider and has a gentle slope, human settlement has become possible, and the city has expanded into those areas. In contrast, wherever the valley is narrower, the city has taken on a narrow and elongated shape. Therefore, it can be said that the city has a linear and elongated appearance, which has become wider in some locations. The Khorramroud River, with a width of 30 to 75 meters, also flows from north to south along the land slope through the city. The Karganeh River, which is usually 6 to 30 meters wide, joins the Khorramroud in the middle of the city (Mohajeri, 2012).

In addition to physical constraints, a set of economic, social, and climatic factors has also influenced the housing construction pattern in the city of Khorramabad. In the southern areas, due to greater heat and less climatic comfort, lower construction costs, and the traditional and tribal social fabric, the housing construction pattern has predominantly tended toward single-family detached houses (villas). In contrast, the central areas, as the main hub of economic activities, have the highest level of employment, land prices, and building density, and given the high value of land, the apartment residential pattern has become dominant there. In some northern areas, considering the more favorable environmental and climatic conditions and the relatively high value of land, the extent of apartment construction has expanded. In this way, the further one moves from the city center, the more the housing construction pattern shifts toward single-family detached houses (Farokhi et al., 2023, p. 57). In this context, factors such as the small size of housing units in old urban fabrics, the large volume of deteriorated fabrics in need of reconstruction, the existence of developable vacant lands within deteriorated fabrics, the high price of land and housing, bank facilities, the possibility of increasing density in certain capable areas, the people's willingness to invest in the reconstruction of certain deteriorated fabrics due to high added value, low per capita income, and consequently the weak financial capacity of citizens, play a fundamental role in the future of housing planning in the city of Khorramabad (Moradi monfared et al., 2025: 159).

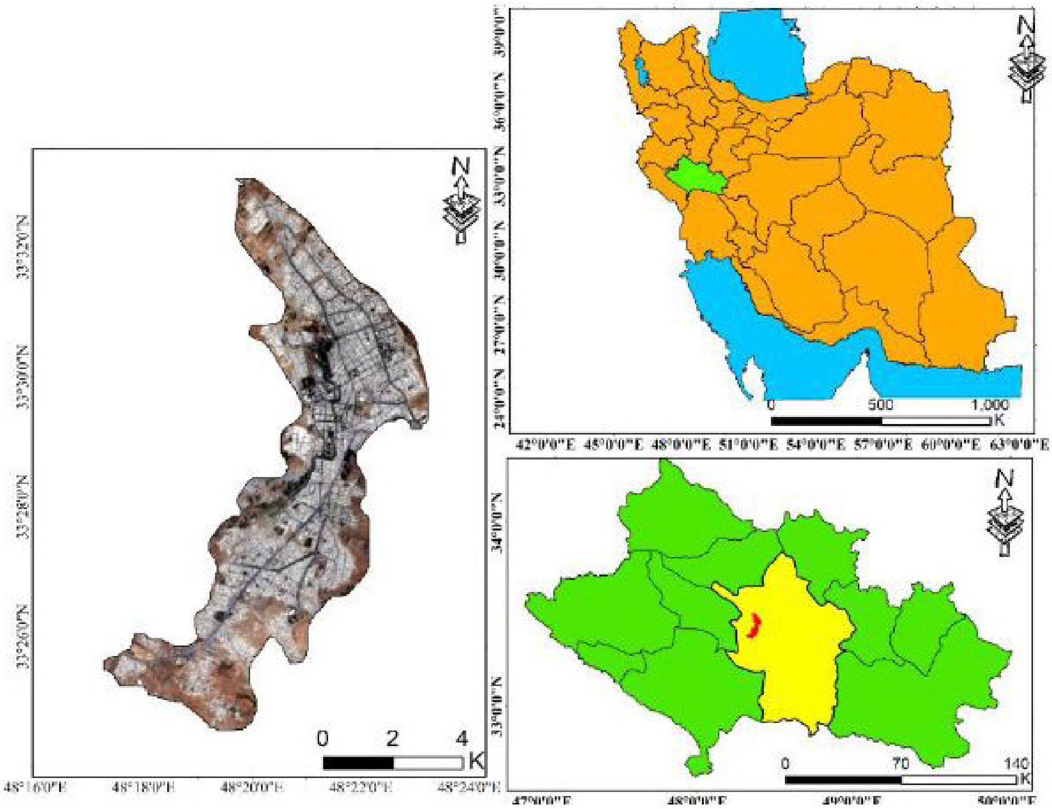

Figure 2. Geographical location of Khorramabad (Abdeshahi, 2026: 6)

4.2. Econometric model specification

The traditional model of the housing production function was developed and presented by Muth between 1969 and 1971. In this model, it is assumed that housing is a homogeneous and divisible good, the supply and demand of which generate a continuous flow of housing services; the input and product markets are under perfectly competitive conditions; and all housing producers have identical production functions, in which the maximum quantity of housing is produced by the stock of land and capital applying a given technology. In fact, capital is considered a combination of non-land and mobile factors that is constant across all locations within an urban area. Therefore, land (LA) and capital (NLA) are considered the main inputs in the production of housing goods, and the housing production function can be written as follows:

$$Q = f(LA, NLA) \tag{2}$$

Assuming that housing producers are perfectly competitive in the product and factor markets, the following conditions must be met for producers to maximize their revenue.

$$\frac{\partial Q}{\partial LA} = \frac{r_{LA}}{P} \qquad (3)$$

$$\frac{\partial Q}{\partial NLA} = \frac{r_{NLA}}{p} \qquad (4)$$

where r_{LA} is the price per square meter of land, r_{NLA} is the construction cost per square meter of residential floor area, and p is the unit selling price of the building. If f(LA,NLA) has a CES, it can also be written as follows:

$$Q = [\alpha LA^{-\rho} + \beta NLA^{-\rho}]^{-\frac{1}{\rho}} \qquad (5)$$

In the CES production function, the parameters β, α and ρ are constant. Using the above relationship, CES between land and capital can be estimated according to the following model.

$$Log\left(\frac{r_{LA}LA}{r_{NLA}NLA}\right) = \beta_0 + \beta_1 Log\left(\frac{r_{LA}}{r_{NLA}}\right) \quad , \qquad \sigma = 1 - \beta_1 \qquad (6)$$

The ratio of land value (r_{LA}LA) to the total construction cost of the building (r_{NLA}NLA) is a log-linear function of the relative price of land to capital. CES is also obtained from the relationship. $\sigma = 1 - \beta_1$

Housing supply models with the CES production function assume the elasticity of substitution to be constant. However, the elasticity of substitution can be variable (VES) and change as the capital-to-land ratio changes. The Revankar production function is one type of production function with VES, which is written as follows.

$$Q = \gamma NLA^{\alpha(1-\delta\rho)}[LA + (\rho - 1)NLA]^{\alpha\delta\rho} \qquad (7)$$

In this equation, α, γ, δ, ρ and are parameters that have the following constraints:

$$\gamma > 0\,, \qquad \alpha > 0\,, \qquad 0 < \delta < 1 \;, \qquad 0 \le \delta\rho \le 1 \;, \qquad \frac{LA}{NLA} > \left(\frac{1-\rho}{1-\delta\rho}\right) \qquad (8)$$

Based on the above function, VES can be obtained according to the following econometric model.

$$\frac{r_{LA}LA}{r_{NLA}NLA} = \beta_0 + \beta_1\left(\frac{r_{LA}}{r_{NLA}}\right) \quad , \qquad \beta_0 = \frac{\delta\rho}{1-\delta\rho} \quad , \qquad \beta_1 = \frac{1-\rho}{1-\delta\rho} \qquad (9)$$

The average elasticity of substitution is obtained by having the value of β_1 To do this, the mean value of $\lambda = E\left(\frac{r_{NLA}}{r_{LA}}\right)$ is calculated (Erol & Güzel, 2006, pp. 89-91).

$$\bar{\sigma} = 1 + \frac{\rho - 1}{1 - \delta\rho}\lambda \qquad (10)$$

4.3. Data and information collection

The present research is applied in terms of its purpose and descriptive-analytical in terms of its nature and method, based on econometric techniques. The primary objective of the research is to examine the degree of substitutability between land and capital in urban housing production in Khorramabad, applying housing production functions.

The statistical population of the research comprises the blocks[1] within the urban area of Khorramabad, which initially included 110 blocks. After reviewing and eliminating non-residential blocks and blocks for which transaction information was not accessible, the number of examinable blocks was reduced to 100 blocks. A stratified sampling method was employed for data collection. In this method, each urban block was considered as a stratum. The selection of this method was due to the spatial heterogeneity of urban blocks in terms of land prices, building density, and construction patterns, so that the samples could serve as an appropriate representation of the actual conditions of the housing market across the city. Within each block, a number of real estate agency offices were selected randomly, proportionate to the size of the block and the building density.

The required information was collected in the year 1403 (2025) through field visits to real estate agency offices and the examination of property transaction data. The selection of real estate agency offices as the data source was made due to their direct access to transaction information and their awareness of actual housing market prices. The collected data included land prices, average land area, construction costs, total floor area of buildings, and the price per square meter of residential space (including both single-family detached houses and apartment units).

The main variables used in this research include land price (r_{LA}), the amount of land used in the building (LA), the construction cost per square meter of floor area (r_{NLA}), the total floor area of the building (NLA), and the building value (pQ), where building value is obtained from the product of the price per square meter of residential space (p) multiplied by the total floor area of the building (Q). The selection of these variables is based on the theoretical foundations of land and housing economics, and particularly the Muth housing production function model; within this framework, land and capital are considered the two main inputs in housing production, and the analysis of the relationship between them is essential for examining the housing supply structure.

In the next stage, considering the spatial differences in the land and housing market across the city, the studied blocks were classified based on their geographical location into three levels: central, intermediate, and peripheral. This classification was carried out with the aim of examining the structural differences in the housing market across different parts of the city.

Finally, the collected data were analyzed using econometric models based on housing production functions. For this purpose, the CES production function and the VES production function were used, and the parameters of the models were estimated using the OLS method. Based on the estimated coefficients, the elasticity of substitution between land and capital in housing production was calculated and analyzed.

5. Results

The results obtained from estimating the elasticity of substitution between land and capital inputs at the level of the entire city, the city center, and the city periphery for the CES and VES production functions, applying the OLS method, are presented in Tables 1 and 3. The coefficients and the models are generally significant and possess an acceptable explanatory power.

In order to ensure the validity of the estimates and the accuracy of statistical inference, the White test for heteroskedasticity was evaluated on the estimated models. The test results for all estimated models indicate that the null hypothesis cannot be rejected.

Table 1. Estimation results of the elasticity of substitution between land and capital for the CES function

	Intercept (std. error)	t-Statistic (prob.)	$Log\left(\frac{r_{LA}}{r_{NLA}}\right)$ (std. error)	t-Statistic (prob.)	Elasticity	F-Statistic (prob.)	R-squared
City periphery	0.256 (0.0288)	8.9 (0.0000)	0.33 (0.024)	13.51 (0.0000)	0.665	182.74 (0.0000)	0.75
City center	0.299 (0.052)	5.75 (0.0000)	0.34 (0.033)	10.25 (0.0000)	0.658	105.13 (0.0000)	0.73
Entire city	0.272 (0.02)	13.53 (0.0000)	0.35* (0.017)	19.55 (0.0000)	0.648	382.5 (0.0000)	0.79

* It is significant at the 0.99 confidence level.

Table 2. White heteroskedasticity test for the CES function

	F-Statistic	Prob.
City periphery	1.207	0.306
City center	0.389	0.68
Entire city	0.569	0.567

The results obtained from estimating the CES model indicate that with a 100 percent increase in the price of land relative to construction costs, housing builders in the city of Khorramabad, on average, substitute building in height for building on the surface of the residential building by approximately 64 percent in the entire city, 65 percent in the city center, and 66 percent in the city periphery. The results obtained at the entire city level for the CES function can be written as follows.

$$Log\left(\frac{r_{LA}LA}{r_{NLA}NLA}\right) = 0.272 + 0.351Log\left(\frac{r_{LA}}{r_{NLA}}\right) \ . \ \sigma = 1 - \beta_1 = 0.648 \qquad (11)$$

Examining the findings obtained from estimating the CES production function reveals a significant pattern of builders' responsiveness to relative changes in land prices. The results indicate that with a relative increase in land prices, the tendency to substitute capital for land (increasing height) is greater in peripheral areas than in central areas, and greater in central areas than in the entire city. In the city periphery, in addition to the existence of low density and more flexible regulations, there is a relative abundance of land and lower land prices. These conditions reduce financial pressure on builders and provide the possibility of input substitution with greater ease for builders. In contrast, in central areas, there is a greater incentive to increase height in response to relative changes in land prices, due to constraints such as high density, infrastructure, and stringent municipal regulations on increasing height, the high share of land price in the total cost of the building, and executive complexity in crowded environments, the possibility of substitution is less than in the city periphery. However, the elasticity in the city center was observed to be greater than in the entire city; this is because the average of the elasticity was taken across different areas, reflecting the effect of density constraints and land supply on overall flexibility.

Table 3. Estimation results of the elasticity of substitution between land and capital for the VES function

	Intercept (std. error)	t-Statistic (prob.)	$\left(\frac{r_{LA}}{r_{NLA}}\right)$ (std. error)	t-Statistic (prob.)	Elasticity	F-Statistic (prob.)	R-squared
City periphery	0.423 (0.071)	5.94 (0.0000)	0.41 (0.102)	3.98 (0.0000)	0.719	122.9 (0.0000)	0.679
City center	0.358 (0.061)	5.83 (0.0000)	0.263 (0.056)	4.66 (0.0000)	0.684	88.19 (0.0000)	0.698
Entire city	0.372 (0.056)	6.58 (0.0000)	0.356 (0.05)	7.07 (0.0000)	0.691	251.17 (0.0000)	0.719

Table 4. White heteroskedasticity test for the VES function

	F-Statistic	Prob.
City periphery	0.715	0.493
City center	0.356	0.702
Entire city	1.361	0.261

Estimating the VES model provides the possibility of variability in elasticity based on the level of input consumption and its share in production. The estimates show that with a 100 percent increase in the price of land relative to construction costs, housing producers in the city of Khorramabad, on average, increase the substitution of capital for land by approximately 69 percent in the entire city, 68 percent in the city center, and 71 percent in the city periphery, and try to compensate for the lack of horizontal space through vertical development. The results obtained at the entire city level for the VES function can be written as follows.

$$\frac{r_{LA}LA}{r_{NLA}NLA} = 0.372 + 0.356\left(\frac{r_{LA}}{r_{NLA}}\right) \quad , \qquad \sigma = 0.691 \qquad (12)$$

Applying the VES model, the urban periphery demonstrated not only the highest elasticity of substitution between inputs but also greater flexibility. However, the order of the other areas differs; the elasticity for the entire city is greater than that for the city center. The lower substitutability between inputs in the city center compared to the city periphery further highlights the role of density constraints and stringent regulations. In other words, producers often face greater substitution constraints compared to the city periphery. The elasticity for the entire city is an average of the entire urban fabric and represents the average ability to substitute inputs. Also, the higher dispersion of the variable elasticity in the city periphery indicates greater fluctuations in the response of inputs to changes in the production level and the combination of land and capital, compared to the city center and the entire city.

6. Discussion and conclusion

The special position of housing in economic and social affairs, along with its unique characteristics, has distinguished housing from other produced goods. Accordingly, analyzing how housing is produced, the manner in which inputs are utilized, and understanding the reaction of producers in the face of rising input prices is of particular importance. This importance is doubled for policymakers and planners in regions that face supply constraints for one of the inputs.

In this research, an attempt was made to calculate the elasticity of substitution between land and capital inputs in housing production in the city of Khorramabad. Data was collected using a stratified sampling method and through field observations. In order to achieve a richer analysis of the behavior of housing producers, two production functions—CES and VES—were selected. The elasticity of substitution between land and capital for the CES function at the level of the entire city, the city center, and the city periphery was calculated as 0.648, 0.658, and 0.665, respectively. These results for the VES function were estimated as 0.691, 0.684, and 0.719, respectively. Overall, these results indicate that the percentage increase in building heights is less than the percentage relative increase in land prices, and the flexibility of input substitution is at a limited level.

The analysis of the elasticity of substitution between land and capital in the housing sector of the city of Khorramabad using the CES and VES models shows that the flexibility of input substitution in different urban areas is influenced by the characteristics of the urban fabric, density, land prices, and the input supply structure, and different patterns are observed across the entire city, the center, and the periphery.

A comparison of the estimated coefficients in the two models indicates that the type of model has a significant impact on the magnitude of the elasticity. The coefficients obtained in the VES model are slightly higher than those in the CES model. In the CES model, the order of flexibility is periphery > center > entire city, whereas in the VES model, the order is periphery > entire city > center. These differences stem from the nature of the models, such that the CES demonstrates an inherent and constant substitutability, while the VES model takes into account the actual and level-dependent flexibility based on input consumption and their share in production, and possesses greater variability.

A comparative analysis of the results of the present research shows alignment with the findings of some domestic and foreign studies, such as Shakarmi (2018), Zhang et al. (2022), Ahlfeldt and McMillen (2018), Batisani and Yarnal (2011), and Erol and Güzel (2006)—research that emphasized the limited possibility of substituting capital for land. In contrast, it differs from the studies of Yarmohamadian and Salarvand (2020), Vikkelsø (2024), and Epple et al. (2010), which estimated the elasticity of substitution to be greater than one. The differences observed in the reported degree of elasticity of substitution between land and capital inputs in various cities can be attributed to factors such as the level of economic development, construction technology, input prices, market conditions, regulations governing urban density, land use restrictions, and the geographical location and physical structure of the city.

Given that the elasticity of substitution between land and capital inputs in housing production in the city of Khorramabad is less than one, and land is considered an input with limited substitutability whose price fluctuations have a significant effect on the final cost and price of housing, the optimal use of existing land is of great importance. Accordingly, it is suggested that the government, through the release and transfer of surplus and unused lands belonging to its agencies to the private and cooperative sectors, facilitate the possibility of greater housing supply. Alongside this, the implementation of reconstruction and renovation plans for deteriorated urban fabrics—such as Posht-e Bazar, Posht-e Hossein-Abad, Jazam, and Meydan-e Tir, which are also located in suitable parts of the city—can increase residential capacity without putting pressure on land resources. This measure, in addition to increasing housing supply, will also lead to the improvement of the quality of life for citizens.

Considering the decline in the purchasing power of Iranian households in recent years and the increased demand for housing in peripheral areas, and taking into account the fact that the elasticity of substitution of capital for land in these areas is greater than in the city center and the entire city; should financial resources be provided to housing builders in the peripheral areas of the city, it would not only increase the incentive to enhance housing supply and production but would also create conditions for better household access to residential units. It is also suggested that the municipality, by adjusting density policies in central areas, commensurate with infrastructural capacity and limited land management, provide the possibility of a more balanced response to housing market fluctuations in the city of Khorramabad.

In addition to the above measures, the use of modern construction technologies, lightweight and durable materials, and up-to-date engineering principles can play an important role in increasing land and capital productivity. The application of such tools and technologies reduces the cost of using capital and facilitates the substitution between land and capital. Overall, the combination of these measures with smart management, appropriate financial planning, and the revitalization of existing capacities in deteriorated urban fabrics will not only lead to the optimal use of production resources but will also result in increased housing supply, enhanced construction quality, and improved living standards for citizens.

Authors' Contributions

The contributions of the authors were equal.

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Conflict of Interest

There is no conflict of interest in conducting this research.

EndNote

[1] The urban area is divided into sections that are similar to one another in terms of price. Each of these sections is referred to as a block. To observe the blocks, the transactional value book for each city can be obtained from the Tax Affairs Organization.

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