



Article

Disentangling Housing Supply to Shift towards Smart Cities: Analysing Theoretical and Empirical Studies

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Abstract: The search for a pleasant home has concerned people ever since. Paradoxically, people are facing strong difficulties in finding a decent place to settle their lives in cities. As such, the housing market regained momentum in connection with the development of Smart Cities, where life quality of residents is strongly emphasized. Well-being in the metropolis is affected by a wide variety of factors with housing supply being among the most important, hence stirred by financing costs, construction costs, vacancy rate, sales delay, inflation rate, housing stock, price of agricultural land, and regulation. The present article reviews empirical studies on housing supply for a better understanding of the dynamics in this market, shedding some light on the expectable outcomes of policy actions in the promotion of sustainable housing towards the smart city transition. Our review shows that the long-run price elasticity of housing supply is larger than the short-run, as well as the existence of substantial differences in the price elasticity across countries and regions. As such, overall, the hypothesis of a perfectly elastic supply is rejected. In addition, our review highlights that housing supply is negatively related to financial costs, inflation, sales delay, and the existence of regulatory or physical constraints. Also, the elasticity is lower when there are regulatory constraints. Newfangled strategic interaction models, though overlooked in the literature, reinforce that housing does not fit the perfect competition frame. The review proves that we are in face of a non-competitive market in which policy intervention is required to maximize social welfare; policy packages to grant people access to the housing market may be required. However, policy interventions should be carefully designed and clear, to mitigate their potentially negative impact on the housing supply as adverse results may be harmful to the transition towards a smart city.

Keywords: housing supply; price elasticity of supply; smart cities; strategic interaction models



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1. Introduction

Cities are the home for nearly three-fourths of the European population as well as the bigger contributor to global warming; moreover, cities consume two-thirds of global energy and produce an overwhelming impact on the climate. At present, there is a generalized effort to accelerate the clean-energy transition as the sustainability targets are endangered. Hence, these actors play a key role in addressing the climate challenge and the promotion of better living conditions.

According to the 11th goal of 'sustainable cities and communities', safe and affordable housing, upgraded slum settlements, public transport, green public spaces, and participatory and inclusive urban planning and management, are citizen rights [1]. In this vein, local governments around the world are dealing with the challenge of providing affordable homes to their citizens, as house prices not seldom become unbearable. Average house

prices are rising faster than income, creating important constraints to the population. Urban spaces are becoming means of survival for the less affluent, raising social asymmetries. However, cities are central to winning the battle against global warming being simultaneously consumers of two-thirds of the overall energy and returning with a similar proportion of greenhouse-gas emissions (<https://ec.europa.eu/research-and-innovation/en/horizon-magazine/european-cities-team-expand-clean-energy-cut-fossil-fuels>; accessed on the 25 August 2022). Considering these figures, it urges helping households in their home renovations towards a smarter housing stock.

The increasing urban population posed multiple concerns related to urban management [2,3]. As such, the making of the city “smart” is emerging as a strategy to mitigate the problems generated by urban population growth and rapid urbanization. However, this concept roots back to the 1970s, proposing a virtual and technological configuration of urban spaces [4]. More recently it was proposed as a strategic device to encompass modern urban production factors in a common framework [5,6]. These frameworks articulate models and practices to deal with urban problems such as air and water quality, housing, income, energy, traffic, sanitation, or safety; this strategic planning must encompass the citizen-based approach [7,8].

Increasing infrastructure and capacity while decreasing carbon emissions in cities demands a shift. This change relies upon digitization, smart space management, and energetic efficiency [9,10]. A smart city must therefore include contemporary technologies, buildings, utilities, transportation, and road infrastructure [11].

The housing problem under the smart city framework needs to be discussed in different dimensions (e.g., [12–14]): the energetic system [8], the housing efficiency [15], the automation and intelligence [16], the socio-political organization [17], the urban planning policy action [13], and the environmental improvement [7,15]. Given these multiple challenges and the required adjustments and shifts, the construction and renovation of residential buildings are core towards the promotion of smart and efficient buildings encompassing greener technologies and welfare promotion [14]. Under this frame, the housing stock needs to be disentangled, mainly in what relates to the availability and price of houses meeting these requirements.

In this vein, this paper analyses the literature on housing supply with the purpose of understanding price setting and understanding how far this mechanism is affecting the transition to smarter and livable cities. It is a fact that housing supply remains understudied relative to demand (see, among others: [18–23]). The reason is certainly not the lack of interest, but perhaps, as argues Rosenthal [24], the inexistence of adequate data for empirical studies. Another reason may be the hardship of modeling the housing supply, as referred to by Quigley [18]. The first struggle is that housing services are difficult to measure. The second is that in the housing market we observe price times quantity, unlike other markets where we see the price for a standard unit. The third struggle is that housing supply is the result of the decision-making by land developers and by the actual owners of housing. To understand the micro-foundations of housing supply, we would need data such that the unit of observation is the individual supplier. However, it is very difficult to obtain data on the behavior of land developers. This explains why the great majority of the papers on new housing supply analyze aggregate data. DiPasquale [21] states that there are few papers which use micro data (where the decision maker, the developer, is the unit of analysis).

Most studies in the literature on housing supply involve the estimation of an empirical model, with the objective of identifying the determinants of new housing supply and estimating the price elasticity of supply (PES). Consequently, a great part of this survey covers empirical studies on housing supply and summarizes the findings regarding these two issues.

Although, in some cases, it is hard to identify the theoretical underpinnings of the empirical studies, one can identify two major theoretical foundations: the investment literature and the urban spatial theory. The main difference between these two approaches is the treatment of land. Studies based on the investment theory treat land as an input in

the production of new housing and tend to ignore the special characteristics of the land as a factor of production, while those based on urban spatial theory incorporate the land market into the theoretical structure. Moreover, the models based on the investment theory assume that the home-building industry is composed of competitive firms and that they face rising factor cost schedules for labor and building materials. However, according to the urban spatial theory, land is different from the other factors of production. Land prices depend on the stock of housing, not on the flow or level of building activity. As a result, a rise in house prices initially generates excess returns, but the flow of construction increases only temporarily above the normal level. As the stock of housing grows, land prices rise and eventually absorb the excess returns, and construction declines to its normal level.

The investment theory framework is well illustrated in Poterba [25] and Topel and Rosen [26]. Poterba [25] uses an asset market form to model the housing market and defines supply as net investment in structures. Topel and Rosen [26] consider housing production decisions as housing investment decisions. On the other hand, DiPasquale and Wheaton [27] and Mayer and Somerville [28] are reference papers based on urban spatial theory, which considers the land as an input.

Besides the differences in the theoretical foundations, the studies surveyed also differ in the type of data and estimation techniques used. Two approaches have been used to estimate housing supply: the reduced-form estimation and the structural form estimation. In the reduced-form estimation the equilibrium price is a function of supply and demand factors. On the other hand, in the structural approach the aggregate supply is estimated directly with construction as a function of price and cost shifters.

As mentioned before, it is not always easy to classify empirical papers according to their theoretical foundations, thus we did not attempt to do so. However, we decided to organize the survey of the empirical papers into two distinct subsections. First, we revise the earlier empirical studies, from Maisel [29] to Topel and Rosen [26]. These studies are influenced by the investment theory. Next, we revise the more recent studies, starting with DiPasquale and Wheaton [27], and then discuss the determinants of housing supply.

Moreover, with the influence of the investment theory and urban spatial theory, there is a growing literature that applies game theory and industrial organization to the housing market. We believe that this new branch of the literature can provide an important theoretical contribution to the housing supply and suggest some clues for future empirical research on this theme. We dedicate Section 3 to the review of strategic interaction models.

The remaining of the paper is organized as follows. Section 2 revises the empirical studies, first earlier and then more recent empirical studies. Ensuing, we analyze the determinants of housing supply in the housing market. Section 3 summarizes the strategic interaction models used for the housing market. Finally, the last section summarizes the main conclusions of the paper, proposes some policy implications, and presents avenues for future research.

2. Empirical Literature on Housing Supply

2.1. First Generation of Empirical Studies

Although Maisel [29] provides a description of builders of single-family housing in the USA, namely in the San Francisco area, and the factors that influence their construction decisions, in the literature on housing supply Muth [30] is considered the first empirical study. Muth [30] assumes a neoclassical-efficient-markets view of the housing market, where supply responsiveness is infinitely elastic in the long run. He develops a stock adjustment model and tests the relationship between the price and quantity of new housing construction. He is unable to reject the null hypothesis of a perfectly elastic supply. However, there are several problems with this analysis. One of the problems is the small sample: annual data from 1915 to 1934 and with the war years being omitted. Another critique is the fact that his estimation does not adjust for serial correlation or for the possibility of simultaneity bias between the price and quantity of new housing construction. Olsen [19] also points out significant methodological problems, particularly on the issue of including

both input prices and quantity in the reduced form model. Leeuw and Ekanem [31] use a reduced-form model with information on rent differences among metropolitan areas in the USA to estimate the elasticity of the supply of rental housing. Using cross-sectional data, they estimate two equations and combine the results of the reduced form estimation with information from other studies on the parameters of the demand equation to draw conclusions about the behavior of the supply of housing services. They estimate an elasticity of supply from 0.3 to 0.7, suggesting that the supply of housing is inelastic. In addition, they suggest that diseconomies of scale are one of the sources of this inelasticity. Follain [32] follows the formulation of Muth [30]. He uses annual aggregated data from 1947 to 1975 and employs two measures of the quantity of new housing stock. He finds no significant positive relationship between quantity and price and concludes that the hypothesis of a perfectly elastic long-run supply of new construction cannot be rejected. Using quarterly data from 1955 to 1972 for the UK, Whitehead [33] develops and estimates a series of related stock adjustment models. The results for the PES range from 0.5 to 2.

Another important and very complete study of the price elasticity of housing supply is Rydell [34]. He examines the components of supply response to demand shifts. He argues that the supply of housing services available to consumers can increase in three ways: (i) existing housing can be upgraded by repair; (ii) the housing inventory can be expanded either by using existing residential land more intensely or by increasing the amount of residential land; (iii) the proportion of existing housing that is occupied can be increased. As such, the overall supply elasticity is a composite of these three components. His study supports the conclusion that the repair elasticity is very low, that the inventory elasticity is very large, and that the occupancy elasticity is greater than zero. Using cross-sectional data from 59 metropolitan areas in the USA, in the years 1974 and 1976 and considering a reduced form estimation, he estimates a long-run PES of 11.3. He finds that the short-run PES is lower (0.24 or 0.83), depending on the market occupancy rate.

The attempts to directly model housing supply in the 1980s come from the theoretical background of the investment literature. These models assume that the home-building industry is composed of competitive firms. Two reference studies are Poterba [25] and Topel and Rosen [26].

Poterba [25] models the housing market using an asset approach and defines supply as net investment in structures. He assumes that investment supply depends on real house prices, the real price of alternative investment projects, and construction wage rates. To explain the impact of credit rationing he includes alternative indicators of credit availability. Knowing that houses take time to build, he uses one-quarter-ahead forecasts of real house prices and the real price of alternative investment projects. Since new houses take time to sell, he adjusts real house prices to reflect interest costs incurred during the period from completion to sale. He estimates various linear models using quarterly data from 1964 to 1982. Investment supply is measured as the value of one-family structures put in place or as a rate of new housing investment defined relative to aggregate real output. In the best-fitting models, the elasticity of the rate of new construction with respect to real house prices varies from 0.5 to 2.3. The author detects a significant relationship between credit availability and the rate of housing investment, supporting the “supply effect” hypothesis that credit availability affects the flow of new construction. The measures of construction costs, such as construction wage, produce unexpected signs and have no statistical significance.

Topel and Rosen [26] study new housing supply by considering whether current asset prices are sufficient for housing investment decisions. If they are, then the short-run and long-run investment supplies are identical; if they are not, because of costs associated with moving resources between industries, then the short-run supply is less elastic than the long-run supply. As a result, builders and developers must anticipate future asset prices in making current construction decisions. They incorporate these supply dynamics by specifying the industry’s cost function in terms of both the level and the rate of change in construction, along with cost variables. They estimate a myopic model and then a

model with expectations and internal adjustment costs. In their myopic model, production costs are unaffected by the rate of change in construction activity so current construction decisions are based solely on current asset price and marginal cost. If production costs are affected by the rate of change in construction activity, then internal adjustment costs are present and short-run supply is less elastic than long-run supply. These internal adjustment costs introduce expectations of future asset prices as determinants of new housing supply, since current prices by themselves fail to reflect all relevant information. Using quarterly data for 1963 through 1983, the authors estimate alternative versions of their myopic and internal adjustment cost models. They measure new housing investment as the number of single-family housing starts. The expected real interest rate, the expected inflation rate, the lags of these rates, and alternative measures of construction input prices are included as cost shifters. The number of months from start to sale for single-family homes is included as an indicator of market conditions. In both the myopic and adjustment cost frameworks, nominal interest rates influence construction activity, but construction costs have insignificant effects on housing investment. The myopic model generates new housing supply elasticities ranging from 1.2 to 1.4. They find that the short-run PES is lower (approximately 1). Their empirical results reject the myopic model in favor of the adjustment cost model. Supply elasticities are calculated to reveal the investment impact of both transitory and permanent housing price shocks. The presence of the time to sale variable considerably reduces the magnitude of the supply responses. For their preferred model, a permanent 1% rise in housing price increases housing investment by about 1.7% in the short run and 2.8% in the long run. However, nearly all the change in construction activity occurs within one year. As in Poterba [25], their measures of construction costs do not have a significant impact on housing starts and the cost of capital to the builders is explained by real interest rates. They also conclude that real interest rates and expected inflation have a significant impact on housing starts. They argue that the impact of inflation is difficult to explain and that the magnitude of the coefficient on real interest rates is too big to just reflect the cost of capital. The authors also argue that the impact of inflation may reflect changes in the velocity at which houses are sold at market prices. To test this explanation, they put the median months on the market for new houses. Their results show a significant and negative impact of that variable on housing starts. But again, the effect is too big to reflect the holding costs related to sales delay.

Table 1 summarizes the earlier empirical studies, indicating the country, sample period, estimation method, whether the regression was estimated in levels or differences, and finally the estimates of the PES.

2.2. Second Generation of Empirical Studies (Contemporary)

The contributions from the investment literature, such as Poterba [25] and Topel and Rosen [26], do not consider the importance of land as an input. However, as we know from the literature on urban spatial theory, land is different from other factors of production. Urban spatial theory incorporates the land market in its theory and gives us equilibrium models in which the stock of houses always equals the urban population.

DiPasquale and Wheaton's [27] approach reflects the dynamic nature of housing supply by incorporating a stock adjustment process and a long-run equilibrium framework based on urban spatial theory. The latter theory implies that urban spatial growth generates higher land prices to attract the land necessary for new housing. By definition, the net change in the housing stock equals the difference between new construction and replacement investment. New construction in turn reflects how quickly the housing stock adjusts to its long-run equilibrium level. The long-run equilibrium housing stock depends on housing prices and input prices. This housing supply framework has two important implications for understanding the new housing supply. First, it implies that construction activity reflects the adjustment process as the current stock moves to its long-run equilibrium level. Second, it indicates that the housing price level affects new construction only to the extent that the current housing stock differs from its long-run equilibrium level for

this price level. As such, changes in housing prices rather than their level attract the land necessary for long-run urban spatial growth. DiPasquale and Wheaton [27] specify new construction (housing starts) as a linear function of new housing price, the short-term real interest rate (the real cost of short-term construction financing), the price of agricultural land, construction costs (indices for construction), and lagged housing stock. The change in aggregate employment and the number of months from completion to the sale for new homes are also introduced as indicators of housing market conditions. The authors estimate alternative linear versions of their supply framework using aggregate annual data from 1963 to 1990. They restrict the analysis to single-family housing and measure new construction as the number of single-family housing starts. In all specifications, the coefficient on housing price is significantly positive. Their estimates of the long-run PES range from 1.0 to 1.2. They conclude that the stock adjusts very slowly to its long-run equilibrium through new construction (the rate of adjustment is about 2% per year). On the other hand, real short-term interest rates have a significant negative impact on construction, whereas land costs do not have a significant impact. Just like Topel and Rosen [26] and Poterba [25], the authors did not find a significant relationship between construction costs and the level of construction. Following Topel and Rosen [26], they add months on the market for new homes to the supply equation and they also find that sales time has a large impact on construction. They argue that the magnitude of the coefficients of sales delays and interest costs is too large, and that the importance of those variables indicates that price is not enough to explain housing starts. They also argue that the magnitude of the coefficient appears to be too large to simply reflect holding costs associated with sales delays. They include, as a market indicator, the change in employment, a variable that has a positive impact on construction. Adding this variable and the sales time to the model improved its fit. Lastly, the authors present strong evidence of a gradual price adjustment process in the market for single-family housing in contrast to previous studies that made assumptions of instantaneous market clearing. Their results confirm the idea that the housing market functioning is very different from other financial asset markets.

Blackley [35] uses annual data from the USA for the period 1950 to 1994. The basic model expresses residential construction as a linear function of new housing prices, the prices of construction materials and labor, the real interest rate, and the expected inflation rates. He also considers the effects of land price, lagged housing stock and the price of nonresidential construction. The variables are expressed in levels. The first conclusion is that the new housing supply is relatively price-elastic in the long run. Estimates of the long-run price elasticity of new housing supply range from 1.6 to 3.7. However, in the models with variables expressed in differences, the long-run elasticity is lower, about 0.8. The second conclusion is that nominal interest rates influence the new housing supply directly. Lastly, the temporal properties of each data series should be considered when specifying and estimating time-series models of new housing supply; for example, with variables expressed in levels, supply is elastic, but with explanatory variables expressed in differences, supply is inelastic.

A great majority of the studies that try to estimate the supply concentrates on the problem of single-family housing starts, but DiPasquale and Wheaton [36] study the problem of the supply of multifamily housing. They estimate a construction equation for multifamily rental housing where the level of multifamily construction, measured by the units in structures with more than one unit, depends on how the asset price of rental housing compares with construction costs. Asset prices are a function of rents, vacancies, and the capitalization rate. The estimated model explains variation in construction with rents, vacancies, the capitalization rate, construction costs, lagged construction, and construction by the federal government of the USA. With this model, they estimate a long run rent elasticity of supply of 6.8. The construction costs are statistically significant and have the expected negative sign.

Using quarterly data at Ireland's national level, Kenny [37] estimated a unit price elasticity of supply, concluding that the Irish housing supply is less elastic than the housing

supply in other countries. Wang et al. [38] used data from China, from 1998 to 2009, showing that the Chinese price elasticity of house supply lies between 2.8 and 5.6. Chow and Niu [39] use a simultaneous equations model, for the study of both the demand and the supply of residential housing in China. The data is annual from 1987 to 2012. The supply of housing is explained by the cost of construction and by the relative prices. They conclude that the PES is approximately 0.5. In their paper, Levin and Pryce [40] work out the UK market. They give a great contribution to the problem of the price elasticity of supply, first by demonstrating that it varies over time due to changes in real interest rates. They conclude that increases in the long-run real interest rates lead to house price rises and a low elasticity of supply, this in the absence of restrictive regulation and market imperfections. They also consider how some market imperfections can interact with planning constraints and building regulations to form the response of supply to price changes. They argue that these may lead to cyclical asymmetry in the price elasticity of supply, that is, the propensity for the quantity supplied to respond very slowly to outward shifts of demand, but very rapidly to inward shifts.

In their model, Mayer and Somerville [28] incorporate the time taken in the development process. In addition, they use more recent time series econometrics methods. One of the differences between this model relative to DiPasquale and Wheaton [27] is that they use price and cost changes and not their levels. They argue that housing starts is a flow variable so it should be a function of flow variables. Consequently, they use lagged price changes and lagged cost changes in their model. The results of this model are a price elasticity of housing starts of about 6.0 and a low-price elasticity of the stock of about 0.08. They justify that difference by saying that the low-price elasticity of the stock is due to the fact that housing starts are a small percentage of the stock. They also find that changes in construction costs are not statistically significant, and that time to sales is statistically significant with a large coefficient, which means that time to sales has a significant impact on construction.

Malpezzi and Maclennan [41] estimate the PES of housing for the USA and the UK. Using a long time series for both countries, they split the sample between prewar and postwar years. The results for the PES reveal greater values for the USA in comparison with the UK, concluding that the USA market is more elastic. Moreover, the values of PES are higher in the prewar period both in the USA and the UK. Ball et al. [42] argue that different spatial scales reveal different aspects of the problem. Therefore, they conclude that there is a need for comparing different scales: international, national, local and firm levels. Their study includes an econometric comparison of Britain and the USA/Australia with comparable data sets in order to see if the price elasticities of supply are different, or if the difference arises from the model specification. Their results show that the elasticity of housing supply with respect to the change in prices is larger in the USA than in Britain, supporting that this is not a question of methodology. Their results show that the elasticity of housing supply with respect to the change in prices is greater than the levels elasticity. The local data indicate that the supply elasticities vary a lot and are related to the topology, planning policy, and land-use patterns. The results of the model of supply constructed on firm-level data show great differences in the behavior of the bigger firms from the global market. The largest firms are more responsive to changes in market conditions. The authors argue that there is evidence that the responsiveness of housing supply to market conditions is lower in Britain than in the USA or Australia.

Somerville [43] uses USA data for three metropolitan areas and first introduces micro-data on housing construction costs, discussing the relation between the supply of new housing and the cost of construction in the USA. He estimates a long-run PES from 5.61 to 14.76. He argues that there is an incorrect measure of labor costs in the literature, and he finds that there is a strong and negative relationship between housing starts and construction costs. Follain et al. [44] use quarterly data for four metropolitan areas in the USA. Their econometric model estimates a short-run elasticity between 1 and 2, and a long-run elasticity between 3 and 5. The long-run price elasticity is aligned with other

papers that used national data for the USA. Harter-Dreiman [45] estimates a two-equation vector error correction system and uses panel data. The unit observation is the Metropolitan Statistical Area (MSA), annual data from 76 MSA for the period 1980 to 1998 in the USA. The results indicate an elastic long-run supply function, with a supply elasticity from 1.8 to 3.2, depending on the assumptions about the income and the price elasticities of demand. Green et al. [46] estimate supply elasticities for 45 metropolitan areas in the USA, following the model of Mayer and Somerville [28]. They conclude that the estimates of the PES vary significantly according to the metropolitan area. Metropolitan areas that are strongly regulated show low elasticities, while metropolitan areas that are less regulated show a wider range. In particular, metropolitan areas with low regulation and with fast growth tend to have high price elasticities, whereas those with slow growth have low-price elasticities. They also conclude that population density is an important variable in explaining supply elasticity and that metropolitan areas with high population density have lower elasticities. Hwang and Quigley [47] analyze USA metropolitan areas, considering annual data from 1987 to 1999. They model new housing supply as a function of changes in prices, input costs and macroeconomic conditions, following Mayer and Somerville [28]. The estimated PES is very small, from 0.01 to 0.09, but highly significant. Saiz [48] estimate the PES for the USA, using a time series for the metro areas with a population greater than 500,000. The estimates range from 0.6 to 5.45. They conclude also that housing supply elasticities can be characterized as functions of both physical constrains and regulatory constraints. This is one of the more recent considerations of physical constrains in the estimation of PES. The author concludes that areas that are inelastic are in fact land-constrained by the topography. Aastveit et al. [49] use quarterly data for a panel of 254 USA metropolitan areas, between 1996 and 2017, and consider a single-equation approach. This recent study concludes that the local supply elasticities in the USA have fallen in recent years, namely since 2012. This implies that the price responsiveness to a demand shock can be very high in current days and the increase in quantity should be smaller. Ihlanfeldt and Mayock [50] estimate the supply elasticity with local data from Florida—USA, using panel data of stocks and housing prices for 63 of Florida's 67 counties and consider supply stock-adjustment models like DiPasquale and Wheaton [27]. They obtain an average short-run price elasticity of 2, with a maximum of 8.

Pryce [51] uses data from England, at a local district level, and considers a simultaneous equation model of housing construction. The model compares elasticities of supply between two cross-sectional periods, a boom in 1988 and a slump in 1992. The paper discusses rationality and tests the existence of a backward-bending supply relationship. He concludes that supply is concave in both periods and that it bends backward during the boom period. The author finds a structural break between the boom and the bust period—the elasticity of supply is higher in the slump period (1.03) and smaller in the boom (0.58)-, but he concludes that there are considerable variations across districts. Wang et al. [38] study also the 35 major cities in China and conclude that the significant determinants of the variation in the PES are a geographical constraint, average built-up urban area, the rate of population growth, and restrictions on land use. Accetturo et al. [52], using data from 40 years for more than one hundred Italian cities, bring one of the more relevant recent studies in Europe. The authors estimate a PES of 0.12. This PES is lower in Europe compared with the USA, which is evidence from earlier and from more recent work on the field. We know that the current rigidities in housing supply in European cities derive from historical landmarks. Saiz [48] concludes also that land use restrictions and other government regulations have a big impact: the regulations lower the PES. Accetturo et al. [52] used physical constraints instead of land regulation as determinants of the PES. In more recent years a considerable number of studies used geographical constraints instead of land regulations with a lot of success; in fact, geographical constraints are positively correlated with land regulation.

Table 1. First generation of literature in housing supply.

Author	Country	Sample Period	Level of Data Aggregation	Estimation Method	Levels/ Differences	PES Long-Run	PES Short-Run
Muth [30]	USA	1915–1934 ^(b)	National	OLS	Levels	perfectly elastic	-
Leeuw and Ekanem [31]	USA	1967	39 metropolitan areas	OLS	Levels	0.3 to 0.7	-
Whitehead [33]	UK	1955–1972 ^(a)	National	OLS	Levels	0.5 to 2	-
Follain [32]	USA	1947–1975 ^(b)	National	2SLS	Levels	perfectly elastic	-
Rydell [34]	USA	1974 and 1976	59 metropolitan areas	OLS	Levels	11.3	0.24 to 0.83 ^(c)
Poterba [25]	USA	1964–1982 ^(a)	National	IV	Levels	0.5 to 2.3	-
Topel and Rosen [26]	USA	1963–1984 ^(a)	National	IV	Levels	3	1

^(a) Quarterly data; ^(b) Annual data; ^(c) The short-run PES short-run is 0.24 (with 96% occupancy rate) and 0.83 (with a 90% occupancy rate).

Table 2. The second generation of literature in housing supply (contemporary models).

Author	Country	Sample Period	Level of Data Aggregation	Estimation Method	Levels/ Differences	PES Long- Run	PES Short-Run
DiPasquale and Wheaton [36]	USA	1960 to 1989 ^(b)	National	OLS	levels	6.8	-
Follain et al. [44]	USA	1977–1990 ^(a)	4 metrop. areas	OLS/2SLS	levels	3 to 5	1 to 2
DiPasquale and Wheaton [27]	USA	1963–1990 ^(b)	National	OLS	levels	1 to 1.2	-
Blackley [35]	USA	1950–1994 ^(b)	National	2SLS	levels	1.6 to 3.7 ^(d)	-
Pryce [51]	UK	1988 and 1992	Local aut. level	2SLS	levels	0.58 in 1988 ^(g) 1.03 in 1992	-
Somerville [43]	USA	1979–1991	3 metrop. areas	IV	differences	5.61 to 14.76	-
Mayer and Somerville [28]	USA	1975–1994 ^(a)	National	IV	differences	6	-
Malpezzi and Maclennan [41]	USA and UK	USA: 1889–1994 ^(c) UK: 1850–1995 ^(c)	National	OLS	differences	UK: Prewar: 1–4; Postwar: 0–1; USA: Prewar: 4–10; Postwar: 6–13	-

Table 2. Cont.

Author	Country	Sample Period	Level of Data Aggregation	Estimation Method	Levels/Differences	PES Long-Run	PES Short-Run
Kenny [37]	Ireland	1975–1998 ^(a)	National	OLS/IV ARDL ^(f)	levels	1	-
Harter-Dreiman [45]	USA	1980 to 1998 ^(b)	76 metropolitan areas	OLS/GLS	differences	1.8 to 3.2	-
Meen [55]	UK	1973–2002 ^(a)	English regions	OLS	differences	0 to 0.84	-
Green et al. [46]	USA	1979–1996 ^(b)	45 metrop. areas	IV	differences	1.43 to 21.6 ^(e)	-
Hwang and Quigley [47]	USA	1987–1999 ^(b)	75 metrop. Areas	2SLS	differences	0.01 to 0.09	-
Saiz [48]	USA	1970–2000	95 metro areas	FGLS	differences	0.6 to 5.45	-
Ball et al. [42]	USA	1977–1990 ^(a)	National: USA; GB and Australia	OLS/2SLS	differences	USA: 3 to 3.5 GB: 1	-
Wang et al. [38]	China	1998–2009 ^(a)	National and city level (35)	OLS	differences	National: 2.8 to 5.6 City: −7.7 to 37.05	-
Ihlanfeldt and Mayock [50]	USA	1990–2010 ^(b)	Local: 63 of Florida’s 67 counties	OLS	levels	-	Average of 2; max. of 8
Chow and Niu [39]	China	1987–2012 ^(b)	National	2SLS	differences	0.523	-
Aastveit et al. [49]	USA	1996–2017 ^(a)	254 metropolitan areas	IV	differences	1996–2006: 2.63 (p. 50)	-
Accetturo et al. [52]	Italy	1971–2011	103 cities	IV	differences	2012–2017: 1.75 (p. 50) ^(h) 0.12	-

^(a) Quarterly data; ^(b) Annual data; ^(c) dropping the war period; ^(d) The model with variables expressed in differences yields PES of 0.8; ^(e) PES statistically greater than zero in 23 of 43 metropolitan areas; ^(f) ARDL (autoregressive distributed-lag); ^(g) The Boom period was 1988 and the slump period 1992, in this article the PES corresponds to the weighted average of short-run and long-run; ^(h) Estimated elasticities for the median percentile 50. The authors also have them for percentiles 10 and 90.

Malpezzi and Mayo [53] indicate that there are significant differences in supply elasticities between countries. They argue that those differences seem to be correlated with the stringency of the regulatory framework in place for land and housing developers. Goodman [54] also says that supply conditions vary within a country. Meen [55] states that, in comparison with the USA, the price elasticities of supply in England are low and that England's price elasticities of supply have been falling since 1970. He concludes that the PES is low in all regions of England (price elasticities are approximately 0 since 1990 in all of them). He argues that it is difficult to incorporate information about planning controls into the time-series models, although that may partially explain the results as Malpezzi and Mayo [53] state. By introducing dummy variables, the paper concludes that there are additional factors that explain the low PES.

The comparative analysis provided by the two generations of models that can be performed comparing Tables 1 and 2 prove that the estimate of the long-run PES of housing varies considerably across studies. However, excluding some earlier studies like Muth [30] and Follain [32], we can reject a perfectly elastic supply of housing, and we can conclude that at least in the long-run supply is elastic with respect to price. Another conclusion that can be extracted across studies is that the PES of housing varies at a regional and a local level. There are several studies that conducted this analysis and draw the same conclusion. We can state that the short-run PES is lower than the long-run PES. We can also state that the results vary with the econometric models used and with the specification. For example, the use of variables in differences seems to lead to lower values in the long-run PES of housing. Lastly, there is evidence of significant differences in supply elasticities between countries. We can conclude also from recent studies that the PES of housing is higher in the USA than in the UK.

2.3. Determinants of Housing Supply

In the last two subsections, empirical studies were systematically analyzed. In this subsection the regressors of the housing supply models are summarized. However, it is worthwhile to summarize the various categories of explanatory variables that were used as well as the results that have been obtained. This will give us an overall picture of the results from the existing empirical evidence.

The set of explanatory variables and the results regarding their impact on housing supply have varied across studies. Classifying the regressors into eight categories, Table 3 shows selected references that include in their study that category of regressors.

Table 3. Selected references for each category of regressors.

Category of Regressors	Selected References
Financing costs	Follain [32]; Topel and Rosen [26]; DiPasquale and Wheaton [27]; Blackley [35]; Mayer and Somerville [28]; Kenny [37]; Meen [55]; Hwang and Quigley [47]; Ball et al. [42]; Wang et al. [38]; Ihlanfeldt and Mayock [50]
Construction costs	Follain [32]; Poterba [25]; DiPasquale and Wheaton [36]; DiPasquale and Wheaton [27]; Blackley [35]; Somerville [43]; Mayer and Somerville [28]; Kenny [37]; Harter-Dreiman [45]; Meen [55]; Saiz [48]; Ball et al. [42]; Wang et al. [38]; Ihlanfeldt and Mayock [50]; Chow and Niu [39]; Aastveit et al. [49]
Vacancy rate	Leeuw and Ekanem [31]; DiPasquale and Wheaton [36]
Sales delay	Topel and Rosen [26]; Mayer and Somerville [28]; DiPasquale and Wheaton [27]; Ball et al. [42]
Inflation rate	Topel and Rosen [26]; Blackley [35]; Aastveit et al. [49]
Stock of housing	Follain et al. [44]; DiPasquale and Wheaton [27]; Blackley [35]; Mayer and Somerville [28]; Malpezzi and Mclennan [41]; Ihlanfeldt and Mayock [50]
Price of agricultural land	DiPasquale and Wheaton [27]; Blackley [35]; Ihlanfeldt and Mayock [50]
Regulation or Topography	Pryce [51]; Green et al. [46]; Hwang and Quigley [47]; Saiz [48]; Ball et al. [42]; Aastveit et al. [49]; Accetturo et al. [52]

As we can see by the number of references in Table 3, the most common regressors are those related to financing costs and construction costs.

To have a clearer view of the sign and significance of the regressors classified in the same category in Table 3, Table 4 summarizes the number of papers where each regressor is statistically significant, with positive or negative impact, and the number of papers where each regressor is not statistically significant.

Table 4. Results of the empirical studies by category of regressors.

Category of Regressors	Positive	Negative	Not Significant
Financing costs	-	10	1
Construction costs	5	7	3
Vacancy rate	-	1	1
Sales delay	-	3	1
Inflation rate	-	3	-
Stock of housing	1	3	2
Price of agricultural land	1	1	1
Regulation or topography	-	6	1

In the category of financing costs, which includes the interest rate in various forms, almost all empirical studies conclude that the cost of financing negatively influences the housing starts. This result is consistent with theory.

Theoretically, construction costs should be an important determinant of housing supply and should have a negative sign, reflecting the negative relation between housing starts and construction costs. However, Table 4 shows that the results for the category of construction costs (which include material costs, wage costs, or an index of both) are inconclusive. Although the expected negative impact is attained in seven papers, five papers show a positive impact and in three other papers construction costs are not statistically significant. As DiPasquale [21] refers, most of the empirical literature on housing supply faces the problem of construction cost measurement. Thus, one possible explanation for the inconclusive results is the quality of the data used to measure these costs. It is interesting to note that studies that use more disaggregated data, such as Somerville [43], conclude that the variable has a significant and negative impact on housing supply.

The vacancy rate appears in only a few papers, being included in two papers as a regressor. One of these papers finds a negative impact, in accordance with theory, while the other paper finds out that the variable is not statistically significant. Sales delay is included only in four papers. However, its impact on housing supply is negative and statistically significant in three papers reviewed, which is theoretically consistent: if the houses take a very long time to sell, the consequence is fewer housing starts. It is also worthwhile to note that the magnitude of the impact of sales delay is quite big in the papers that include this variable. The three papers that include the inflation rate as a regressor show a significant and negative effect on housing starts, which is also consistent with theory. The evidence regarding the impact of the stock of housing (normally with a lag) on housing starts is inconclusive: three papers reveal a negative impact, two papers show a non-significant impact, and one paper finds a positive impact. Similarly, the effect of the price of agricultural land is also not clear, as the three papers that include this variable reach completely different results.

In the category of regulation we included the planning controls, which are used in five papers. The reason why this type of regressor is not used more often is probably related to the lack of information, since it is difficult to have a time series of this variable. In theory, when the regulatory controls are more restrictive there are fewer housing starts, hence the sign of the coefficient should be negative. Four of the five papers that include regulation show the expected theoretical result, whereas in one paper the variable is not statistically significant. It is important to mention that Green et al. [46] conclude that metropolitan areas that were more regulated have lower PES. In some of the more recent papers, like Accetturo et al. [52] and Saiz [48], physical constraints are used instead of land regulation

as a determinant of PES, this regressor is statistically significant and has the expected negative sign.

2.4. Strategic Interaction Models

In the previous subsections, we revised the empirical literature on housing supply. However, within the housing supply literature there are other studies that we would like to highlight. We also review the application of game theory and industrial organization to model housing supply. Unfortunately, as we will show, there are very few studies in this area.

One of the most important applications of game theory to the housing market is Baudewyns [56]. This paper focuses on the strategic interactions of land developers in an imperfectly competitive market, analyzing the decisions made by two land developers that decide two variables independently: price and quality. He assumes that one firm is in the Central Business District (CBD) and builds houses in this location while the other builds in a more decentralized area. In the first stage the duopolists choose the level of housing quality, where the quality is defined as a function of accessibility and housing quality. In the second stage, the two firms simultaneously compete in prices to attract potential clients. The author concludes that the decentralized developer can adopt two kinds of strategies depending on the distance and the anticipated level of quality at the CBD. If the centralized land developer offers high-quality apartments, then the decentralized developer offers low-quality housing units in the CBD. The decentralized developer's reasoning is to differentiate its residential quality to soften price competition in the second stage. In the suburban areas, it offers a higher quality of housing, but the residential quality is lower, because of the transportation costs. Another important paper on housing supply examines the home-building industry and its structure. Somerville [57] states that his paper is the first analytical treatment of the industrial organization of housing supply. He says that traditional studies of housing markets assume that house building is a perfectly competitive industry. Metropolitan area level data on the average size of homebuilder firms and homebuilder market concentration is used to analyze the market structure of the industry. The author concludes that there is a systematic variation across metropolitan areas in the housing market. This variation occurs in the average size of builders and the market share for the largest builders. Hence, he argues that the results are more consistent with treating the industry as monopolistically competitive. He also concludes that homebuilders are larger in more active housing markets, and they are also larger where there is a bigger supply of developed land adequate for larger developments. The author argues that the type of regulating jurisdiction that establishes land-use regulation has an influence on the builder size and market concentration. Wang and Zhou [58] study one well-documented problem in the real-estate markets literature: the excess vacancy or overbuilding in the market. They model overbuilding as a two-stage infinite-horizon non-cooperative game between land developers. In the first stage, each developer simultaneously and independently decides to build a certain number of real properties to meet the demand level. In the second stage, given the available supply and demand of the market, developers select the optimal rental price for their properties. They conclude that it is natural to observe oversupply in real-estate markets, since developers have the incentive to build once they find a development opportunity. Therefore, developers as a whole will supply more houses into the market than the level of demand. After the oversupply, developers will stop building until demand absorbs the existing supply. Their model explains the long-lasting overbuilding in real-estate markets without some traditional explanations such as agency costs, irrational behavior, or uncertainty of demand.

Ball [59] examines the way that the housebuilding industry is organized and tries to identify some implications for the wider operation of housing markets. He argues that there are several characteristics of the industry that seem to reject the idea of a competitive industry. First, there are different institutional forms within and across countries, and housebuilding industrial structures vary considerably. Second, firms adopt strategies, and

they know, from experience, that they are important in determining profit. The author states that strategic behavior cannot have an effect on market outcomes in a competitive model. The paper analyzes potential economies of scale, market factors, information asymmetries, regulation, and risk. He argues that the great variety of ways in which housing is built is not the reason that explains its industrial organization. Factors like market instability, locational specificity, the markets where the houses are sold, information, strategic behavior, regulation in labor markets, land availability, and the regulation, affect the size of firms. He also states that strategic behavior is important in this industry, particularly through behavior regarding the land market and residential development strategies.

Ong et al. [60] apply a game theoretic Nash equilibrium approach to the issue of planning flexibility within land use zoning. The paper is based on the land use planning in Singapore and focuses on the “white sites” program in that country. They claim that flexibility in land use may be valuable, but it potentially introduces a supply inefficiency through uncertainty in the development decision-making process. The main proposition is that interaction between developers of proximate sites may result in a suboptimal supply situation. They demonstrate that a first-mover advantage exists such that subsequent “white sites” released shortly after the first “white sites” are likely to fetch lower land prices.

Chu and Sing [61] incorporate strategic interaction in the modeling of optimal timing decisions for real-estate development projects. They examine the subgame perfect equilibrium strategies for a duopoly real option model, with two firms with asymmetric demand functions. Facing preemptive threats, firms may forgo the waiting options, and invest earlier than what the monopolistic real option models would predict. In their symmetric duopoly model, firms are identical, and products are homogeneous. Thus, there are no relative advantages in the price function of the first mover over the next one. Short bursts and recession-induced overbuilding are two outcomes in this paper. The model predicts that these two phenomena occur in earlier phases of market cycles, and not in the state of recession. In a market in recession with high volatility, the two firms will choose the waiting strategies. Costa and Samanez [62] apply a mathematical model based on game theory and real options. The basic idea is to have a balance between the supply and demand of houses in Rio de Janeiro (Brazil), considering the effect on the price of the houses and on the attitude of competitors in the market. Using the cost and price parameters of the properties, the model determines the optimal investment strategy. The strategy depends on the relationship between the sale price and construction cost for each investor, and the number of active competitors in the market. LaCour-Little and Yang [63] analyze mortgage products and construct a game theory model of contract choice with uncertain future income and house prices. The results show that deferred amortization contracts are most likely to be chosen in the housing markets with greater price appreciation and by households with a higher tolerance for risk.

Mu and Ma [64] analyze the price decision of land and housing, starting from a model that is composed of a land developer, a real estate developer, and the government. They discuss the equilibrium solutions in a cooperative game and in a non-cooperative game. The results show that cooperation is the optimal strategy and that regulating the tax rate can be an efficient way for the government to increase profit while decreasing the house prices to have social stability. Yue et al. [65] apply a game theoretical model to explain the housing price in Hong Kong. They have a different approach, since they consider that the housing market in Hong Kong is oligopolistic. They present a game with a windfall tax and a game without a windfall tax. In the game without windfall tax, the high land price policy is the result of the Hong Kong market. If the government wants to lower the house price in the market, the suggestion is that they enforce a windfall tax. However, they indicate that there are limitations in the applications of game theory to the housing market, especially in Hong Kong. They state that the pricing strategies are very dependent on specific environmental factors. Another limitation is that the interactions between the government and property developers are very complex and unpredictable.

Samsura et al. [66] study the utility and the limitations of game theory for the analysis and for the prediction of the behavior of the actors in the decision-making process, with regard to the development of land. The paper shows that game theory is useful for identifying strategic land development decisions, showing the different payoffs to stakeholders for their strategies, and selecting the equilibrium where all are better off.

The analysis of the papers that use game theory and industrial organization models applied to the housing market shows that the strategic interaction between land developers is still understudied. We consider that this new branch of the literature can provide an important theoretical contribution to the housing supply and, thus, there is a huge potential in exploring this type of model.

3. Discussion

The design and promotion of effective measures to provide affordable houses in cities are in the agenda of policymakers worldwide. The development of collaborative and community-driven strategies appeared very effective, considering that housing should be taken in the policy action as a basic human need. The urgency of taking effective measures which allow people to decently live in cities while preserving the environment and the energetic challenges are accelerating the pace of the development of innovative technologies and tools to make housing smarter and reasonably priced not only in acquisition but also in use. Several policy instruments are being used, from subsidies to grants or even tax incentives, mainly with the purpose of creating a favorable context to invest in housing and improve responsible living in a metropolis. Communities and local governments need to develop collaborative efforts, notwithstanding, the understanding of the market mechanisms undermining competition is vital as it will facilitate access to housing facilities.

Over the years, various empirical studies have been performed on the housing market. Although some of them use cross-section or panel data sets for metropolitan areas, the great majority uses aggregate time series data. Despite the differences regarding the type of data and econometric estimation methods, the main results are quite consistent across studies. As such, excluding some earlier studies like Muth [30] and Follain [32], we can reject a perfectly elastic supply of housing. Most studies find an elastic housing supply, but there are some studies that obtain below-unit elasticities. The studies that distinguish between short-run and long-run elasticities reveal that the price elasticity of the housing supply is lower in the short run. Moreover, the studies that allow comparisons across countries or regions show that there are significant differences in supply elasticities between countries and regions. For instance, the values of the PES are higher in the USA than in the UK. Regarding the other determinants of housing supply, most empirical results are consistent with the theoretical predictions. For instance, financial costs, inflation, and sales delay influence negatively the housing supply. However, there are also some unexpected results, namely the inconclusive ones with respect to the impact of construction costs. One possible explanation for these inconclusive results is the difficulty in measuring accurately construction costs. Our review of the papers that use game theory and industrial organization models of housing supply shows that there is a lot of potential in exploring this type of model as the strategic interaction between land developers is still understudied.

The paper systematizes the existing literature and shows that there is a need to increase our understanding of the behavior of constructors and land developers, and therefore opens future research avenues. This deeper understanding can come from the development of theoretical models predicting their decisions in a context where there exist strategic interactions between land developers and the estimation of empirical models based on microdata. Strategic interaction models of housing supply may allow us to understand how land developers make their decisions regarding house location and house quality. In turn, this allows us to explore the market structure of the housing market and test if the market is competitive or if the land developers have some oligopolistic power. By using data where the unit of analysis is the land developer, we may be able to resolve some counter-intuitive results such as those obtained with respect to the impact of construction costs.

Extant literature reinforces the impact of transaction costs, the short selling restrictions, and the divisibility of assets on market efficiency. Transaction costs do not exacerbate the inefficiency of the market, reducing the magnitude of bubbles and pushing prices closer to fundamentals. More divisible assets exhibit smaller deviations in prices from fundamentals. Also, short selling restrictions contribute to prolonged bubbles; and experimental real estate markets display larger deviations of prices from fundamental values and promote longer boom and bust cycles and smaller turnover than experimental financial markets. In sum, the existence of solid monitoring and supervision of these markets seems to be fundamental to promoting the existence of a more effective market mechanism. As well, given the essentiality of the assets in the transactions, policy makers can no longer neglect the intervention in these markets if they are aiming for the transition towards smarter metropolises.

4. Final Remarks

4.1. Concluding Remarks

By 2030 more than five billion people will expectably live in cities, and by 2050 this figure will raise to 6.5 billion. These ecosystems are now home for nearly three-quarters of the world's population, consequently being the largest energy consumers and pollutants [67]. At present, the smart city framework is considered a panacea for all urban problems. Given its broad conceptualization, it is encompassed in the majority of urban policy packages, aiming to solve all urbanization matters [68]. The creation of livable ecosystems mixes interconnectedness, sustainability, inclusivity, and prosperity [69].

In its latest developments, the smart city concept has absorbed the sustainable city [3]. Accordingly, cities will play a pivotal role in achieving climate neutrality by 2050, and climate mitigation will be heavily dependent on urban action. Supporting cities in their greener transition is fundamental, and the housing market is one of its pillars. Cities can actively contribute to sustainability mainly by improving quality air, smarter transport, and comfort and energetic consumption in buildings.

The severity and scale of the urbanization problems prove that the topic is worth further examination. The housing market can no longer be neglected by policy action as it will promote sustainability from both the economic, the social, and the environmental perspective, while promoting inclusive and resilient ecosystems in which people can live prosperous lives [3,6]. Hence, understanding the mechanism through which the housing market is driven seems to be a key element in helping the achievement of this dimension of smart cities.

The analysis of the literature on housing supply reveals that there are a great number of empirical studies which focus mainly on the determination of the price elasticity of supply, in the short and the long run, and its determinants. Differing in the complexity of the econometric models, these authors (e.g., [42,47,50]) show that the price elasticity of supply varies across countries (Great Britain, the United States of America, China, Italy, or Australia), regions, and local areas. Estimating the price elasticity of supply in other countries and additionally exploring more regional data and local data of other countries is an area of potential for future research. This literature review shows that there is little knowledge about the price elasticity of supply on the level of the land developer and the determinants of supply in this unit of analysis. In Ball et al. [42] we have one of the few examples of using data at the firm level in determining the price elasticity of supply; they conclude that the supply elasticities are greater for large firms, but we still need more in-depth studies at the firm level.

When analyzing the literature, the most frequent determinants of housing supply are financing costs, construction costs, vacancy rate, sales delay, inflation rate, housing stock, price of agricultural land and regulation. Theoretically, construction costs are a very important determinant of housing supply and there should be a negative relationship between housing starts and construction costs; however, there are some empirical studies that find a positive sign and some authors conclude that construction costs are not a

significant regressor. The use of data at the firm level may help solve this issue. On the other hand, land regulation is a very important determinant of housing supply, as we said before; there are recent papers that use measures of physical constraints as a determinant of housing supply, with good results.

Theoretical studies are relatively unexplored, when compared to the wide literature on empirical studies. Moreover, there is evidence of imperfect competition in the housing market, and thus applying industrial organization models is needed. Our review of game theory and industrial organization models applied to the housing market shows that the strategic interaction between land developers is still overlooked. In consequence, this new branch of the literature can provide an important theoretical contribution to the housing supply research area.

Given the non-competitive nature of the housing market, policy action seems to be required through the implementation of policy packages that will improve the market mechanism. Still, evidence from several case studies reinforces that regulations frequently result in unintended consequences; other policy instruments such as zoning and building codes are no different, and they can bias the organization of economic activity and the overall city structure (e.g., [70]).

The central objective of smart cities is to improve the quality of life of citizens. One of the six characteristics of the smart city concept is smart living, and one of the dimensions of this component is to boost citizens' quality of life when at home. As such, people must occupy smart buildings which are friendly to them and the environment, increasing sustainability and efficiency. To better accomplish this target, the determinants of housing supply need to be monitored and controlled by public authorities, conducting the housing stock towards the sustainability standards.

4.2. Limitations and Future Research

The transition towards a smart city framework is multidimensional. Notwithstanding here we have put the limelight on the housing pillar, other dimensions are lacking in the present analysis. Also, the study does not fully explore the housing market players as it is focused mainly on studies dealing with the determinants of housing supply and its price elasticity, neglecting demand and regulatory actions.

It would be interesting to move forwards to a multidimensional approach adding the other dimensions of the smart city. Another relevant aspect to take into consideration is to further explore the connection between public policy and housing supply, to help in the design of policy interventions.

4.3. Implications and Recommendations

The present analysis brings some implications to theory, to practice, and to policy. Regarding the theory, two important recommendations emerge: the first is the development of theoretical models considering the strategic interaction of land developers and predicting their decisions regarding location and other housing characteristics (including various quality dimensions, such as energetic efficiency). The second recommendation regards empirical studies. We recommend using data where the unit of analysis is the land developer, a path that has already happened in the more recent studies and which should continue. By doing so, one may be able to obtain more robust estimators of the impact of variables, such as the construction costs, that were found to have an inconclusive impact on housing supply in previous studies. In addition, one may be able to estimate the impact of local new housing and land use regulation. Moreover, this type of data may allow us to explicitly study market power in the housing market.

To practice, it is worth underlining that smart transitions are not enacted only by one pillar, but often require the engagement of players at multiple levels. It seems that building inclusive, integrated, and multi-dimensional planning to manage the housing problem is a prerequisite for effective and sustainable transformation into smart cities.

Developing plans and policy packages for smart cities to envision their future and promote economic development is urgent. The management of land development by the public sector may overcome the problems arising from its non-competitive structure. Redistributive/compensation policies may generate spillovers to the community through infrastructures, while regulations may generate affordability and inclusion in the market. The virtuous cycle of “decent urbanization” will rely upon policies that promote the efficient use of land, rational division of space, fair compensations, regulatory measures to protect the livelihoods of citizens, regulations on speculative profits of developers, generation of sustainable and smart facilities, which will improve the overall life quality in the ecosystem to all members. However, if regulation is not properly designed, it may negatively affect the housing supply, with negative impacts on aspects such as housing affordability. Therefore, the great challenge is how to incorporate smart city objectives into the housing market policy interventions without negatively affecting the stock of housing and its quality.

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