CEFAGE-UE Working Paper
2011/18

New housing supply: what do we know and how can we learn more?

Pedro M. M. L. Garcês [1], Cesaltina Pacheco Pires [2]

[1] ESGHT, Universidade do Algarve, Portugal

[2] CEFAGE-UE and Departamento de Gestão, Universidade de Évora, Portugal

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Pedro Miguel Moreira Lopes Garcês
ESGHT, Universidade do Algarve, Portugal

Cesaltina Pacheco Pires
CEFAGE-UE and Departamento de Gestão, Universidade de Évora, Portugal

August 2011

Abstract

This paper reviews the literature on new housing supply. The paper starts by summarizing the results of the empirical studies on housing supply, showing that overall these studies reject the hypothesis of a perfectly elastic housing supply and reveal that housing supply is negatively related with financial costs, inflation and sales delay while showing inconclusive results with respect to the construction costs. In addition, we review a recent branch of the literature on housing supply that uses strategic interaction models. There is evidence that the housing market is not well described by the perfect competition model. Thus, a deeper understanding of housing supply can be achieved by considering theoretical models that take into account the strategic interaction between land developers and by using data where the unit of analysis is the land developer.

Keywords: Housing supply; price elasticity of supply, strategic interaction.

JEL classification: R31; C72; E22; L85

1 Introduction

This paper reviews the literature on housing supply. The focus of our review is the literature on the supply of new housing, so we do not consider the renovation and repair of the existing stock.

While the literature on housing supply has grown in the last years, housing supply still remains understudied relatively to demand. In fact, many authors in their reviews about housing supply conclude that it has been understudied (see, among others, Quigley, 1979; Olsen, 1987;

Smith, 1988; and DiPasquale, 1999). The reason certainly is not the lack of interest but perhaps, as argues Rosenthal (1999), the inexistence of adequate data for empirical studies. Another reason may be the difficulty of modelling the housing supply as referred by Quigley (1979). The first difficulty 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 difficulty 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 articles of new housing supply analyze aggregate data. Like DiPasquale (1999) says, there are few articles that use micro data (where the decision maker, the developer, is the unit of analysis).

Most studies in the literature of 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. As a consequence, a great part of this survey is dedicated to the empirical studies on housing supply and summarizes the findings regarding these two issues.

Although, in some cases, it is difficult 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 in 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 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 for building materials. However, according to the urban spatial theory, land is different from 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 the work of Poterba (1984) and Topel and Rosen (1988). Poterba (1984) uses an asset market form to model the housing market and defines supply as net investment in structures. Topel and Rosen (1988) consider housing production decisions as housing investment decisions. On the other hand, Dipasquale and Wheaton (1994) and Mayer and Somerville (2000) are reference papers based on the urban

spatial theory. Besides the influence of the investment theory and urban spatial theory, there is a growing literature that applies game theory / 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 to future empirical work on this theme. We dedicate section 5 to the review on strategic interaction models.

Besides the differences in the theoretical foundations, the studies also differ in the type of data and estimation techniques used, thus in our literature review we provide information on these two aspects. In the literature there are two approaches that 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 the empirical papers according to their theoretical foundations, thus we did not attempt to do so in this work. However, we decided to organize the survey of the empirical articles in two distinct sections. First, we revise the earlier empirical studies, from Maisel (1953) to Topel and Rosen (1988). These studies are influenced by the investment theory. Next we revise the more recent studies, starting with Dipasquale and Wheaton (1992).

The remaining of the paper is organized as follows. In section 2 we start by revising the earlier empirical studies whereas in section 3 we present the more recent empirical studies. In section 4 we analyze the determinants of housing supply. In section 5 we summarize the game theoretical models that have been used to model the housing supply. Finally, the last section, summarizes the main conclusions of the paper and presents some ideas for future research.

2 Earlier empirical studies

Table 1 summarizes the earlier empirical studies, indicating the country, sample period, estimation method, whether the regression is done in levels or differences and, finally the estimates of the price elasticity of supply (PES).

Although Maisel (1953) provides a description of builders of single-family housing in USA, namely in the San Francisco area, and the factors that influence their construction decisions, in the literature on housing supply the study by Muth (1960) is considered the first empirical study. Muth (1960) 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 relation between price and quantity of new housing construction. He was unable

to reject the null hypotheses of a perfectly elastic supply. However, there are several problems with the Muth (1960) study. One of the problems is the small sample: annual data from 1915 to 1934 and with the war years 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 (1987) 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 (1971) use a reduced form model. In their paper they use information on rent differences among metropolitan areas in the USA to estimate the elasticity of supply of rental housing. Using cross sectional data, they estimated two equations and combined 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. Leeuw and Ekanem (1971) estimate an elasticity of supply from 0.3 to 0.7, suggesting that the supply of housing is inelastic. In addition, they suggest that one of the sources of the inelasticity are the diseconomies of scale.

Follain (1979) follows the formulation of Muth (1960). He uses annual aggregated data from 1947 to 1975 and employs two measures of the quantity of new housing stock. Follain (1979) tests the null hypotheses of a perfectly elastic supply. Like Muth (1960) 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.

Whitehead (1974) used quarterly data from 1955 to 1972 for the UK. With this time series he develops and estimates a series of related stock adjustment models. The results for the price elasticity of supply range from 0.5 to 2.

Rydell (1982) has a very complete study of the price elasticity of housing supply. He examines the components of supply response to demand shifts. Rydell (1982) 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. So 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. Rydell (1982) used cross sectional data from 59 metropolitan areas in the USA, in the years of 1974 and 1976. Using a reduced form estimation he estimates a long run price elasticity of supply of 11.3. He finds that the short-run price elasticity of supply (PES) is lower, 0.24 or 0.83, depending on the market occupancy rate.

Table 1: Summary of earlier empirical studies.

Author	Country	Sample Period	Data level of aggregation	Estimation method	Levels/ Differences	PES long-run	PES short-run
Muth (1960)	USA	1915-1934b)	National	OLS	levels	perfectly elastic	_
Leeuw and Ekanem (1971)	USA	1967	39 metropolitan areas	OLS	levels	0.3 to 0.7	_
Whitehead (1974)	UK	1955-1972a)	National	OLS	levels	0.5 to 2	_
Follain (1979)	USA	1947-1975b)	National	2SLS	levels	perfectly elastic	_
Rydell (1982)	USA	1974 and 1976	59 metropolitan areas	OLS	levels	11.3	0.24 to 0.83 c)
Poterba (1984)	USA	1964-1982a)	National	IV	levels	0.5 to 2.3	_
Topel and Rosen (1988)	USA	1963-1984a)	National	IV	levels	3	1

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

The attempts to directly model housing supply, in the 80's, comes 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 (1984) and Topel and Rosen (1988).

Poterba (1984) models the housing market using an asset approach, he defines supply as net investment in structures. Poterba assumes that investment supply depends on real house price, the real price of alternative investment projects, and the construction wage rate. 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 price and the real price of alternative investment projects. Since new houses take time to sell, he adjusts real house price 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. He 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 the construction wage, produced unexpected signs and no statistical significance.

Topel and Rosen (1988) 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 short-run supply is less elastic than 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, they 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, 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, about 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 of the change in construction activity occurs within one year.

As in Poterba (1984) their measures of construction costs do not have a significative impact on housing starts, the cost of capital to the builders are explained by real interest rates. Topel and Rosen (1988) conclude that real interest rates and expected inflation have a significative impact on 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. They 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 house starts. But again they argue that the effect is too big to reflect the holding costs related to sales delay.

3 Recent empirical studies

The contributions from the investment literature, such as Poterba (1984) and Topel and Rosen (1988), do not take into account 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 on its theory and gives us equilibrium models in which the stock of houses always equals the urban population.

Table 2 summarizes the more recent empirical studies on housing supply.

Table 2: Summary of the more recent empirical studies.

Author	Country	Sample Period	Data level of aggregation	Estimation method	Levels/ Differences	PES long-run	PES short-run
Dipasquale & Wheaton (1992)	USA	1960 to 1989b)	National	OLS	levels	6.8	_
Follain, Leavens and Velz (1993)	USA	1977-1990a)	4 metrop. areas	OLS/2SLS	levels	3 to 5	1 to 2
Dipasquale and Wheaton (1994)	USA	1963-1990b)	National	OLS	levels	1 to 1.2	_
Blackley (1999)	USA	1950-1994b)	National	2SLS	levels	1.6 to 3.7d)	_
Pryce (1999)	UK	1988 and 1992	Local aut. level	2SLS	levels	0.58 in 1988g) 1.03 in 1992	_
Somerville (1999)	USA	1979-1991	3 metrop. areas	IV	differences	5.61 to 14.76	_
Mayer and Somerville (2000)	USA	1975-1994a)	National	IV	differences	6	_
Malpezzi and Maclennan (2001)	USA and UK	USA:1889-1994c) UK: 1850-1995c)	National	OLS	differences	UK Prewar: 1-4 UK Postwar: 0-1 USA Prewar: 4-10 USA Postwar: 6-13	_
Kenny (2003)	Ireland	1975-1998a)	National	OLS/IV ARDLf)	levels	1	_
Meen (2005)	UK	1973-2002a)	English regions	OLS	differences	0 to 0.84	_
Green, Malpezzi and Mayo (2005)	USA	1979-1996b)	45 metrop. areas	IV	differences	1.43 to 21.6e)	_
Hwang and Quigley (2006)	USA	1987-1999b)	75 metrop. areas	2SLS	differences	0.01 to 0.09	_

a) Quaterly data; b) Annual data; c) Droping the war period; d) The model with variables expressed in differences yelds 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

DiPasquale and Wheaton (1994) 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 in order to attract the land necessary for new housing. By definition, the net change in the housing stock equals new construction less 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 price and input prices.

This housing supply framework has two important implications for understanding 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 price rather than its level attract the land necessary for long run urban spatial growth.

DiPasquale and Wheaton (1994) 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 sale for new homes are also introduced as indicators of housing market conditions. They estimate alternative linear versions of their supply framework using aggregate annual data from 1963 through 1990. They restrict their 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 to its long run equilibrium through new construction very slowly, 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 and land costs do not have a significant impact on construction. Just like Topel and Rosen (1988) and Poterba (1984) they did not find a significant relationship between construction costs and the level of construction. Like Topel and Rosen 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 the fit of the model. DiPasquale

and Wheaton (1994) presents 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 confirms the idea that the housing market functioning is very different from other financial asset markets.

In their model, Mayer and Somerville (2000), incorporate the time taken in the development process. In addition, they use more recent time series econometrics methods. One of the differences of this model relatively to DiPasquale and Wheaton (1994) is that Mayer and Somerville 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 is 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 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 and the coefficient is large, which means that time to sale has a significant impact on construction.

A great majority of the studies that try to estimate the supply concentrates on the problem of single-family housing starts but there are two articles that study the problem of the supply of multifamily housing. DiPasquale and Wheaton (1992) estimated 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 the 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, in this model the construction costs obtained in a firm of construction, is statistically significant and has the expected negative sign.

Malpezzi and Mayo (1997) indicates 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 (1998) says that supply conditions vary also within a country. Pryce (1999) used data from England at a local district level and constructed 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 article discussed the rationality and tested the existence of, a backward-bending supply relationship. Pryce (1999) concludes that supply was concave in both periods and that it bends backwards during the boom period. He finds that there is 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.

Blackley (1999) used annual data from USA for the period 1950–1994. The basic model expresses residential construction as a linear function of new housing price, the prices of construction materials and labor, the real interest rate and the expected inflation rates. He also considered 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 new housing supply directly. And the third conclusion, is that 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.

Malpezzi and Maclennan (2001) estimate the PES of housing for USA and for UK. Using a long time series both countries, as we can see from Table 2, they divided the sample between prewar and postwar. The results for the PES reveal greater values for USA comparing with UK, concluding that the USA market is more elastic. Moreover, the values of PES are higher in the prewar period both in USA and UK.

Green, Malpezzi, and Mayo (2005) estimated supply elasticities for 45 metropolitan areas in the USA following the model of Mayer and Sommerville (2000). They conclude that the estimates of the price elasticity of supply varied significantly according to the metropolitan area. Metropolitan areas that were strongly regulated have low elasticities while metropolitan areas that are less regulated have a wide range of behavior. 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.

Meen (2005) states that, in comparison with the USA, the price elasticities of supply in England are low, and that the England's price elasticities of supply have been falling since 1970. He concludes that the price elasticities of supply is low in all the regions of England (price elasticities are approximately 0 since 1990 in all the English regions). Meen 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 (1997) defend. By introducing

dummy variables, Meen (2005) concludes that there are additional factors that explain the low price elasticity of supply.

In their paper, Levin and Pryce (2009) works out the UK market. This paper gives 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 cause house price rises and a low elasticity of supply, this in the absence of restrictive regulation and market imperfections. The article considered also how some market imperfections can interact with planning constrains and building regulations to form the response of supply to price changes. They argue that these may conduce to cyclical asymmetry in price elasticity of supply - the tendency for the quantity supplied to respond very slowly to outward shifts of demand, but very rapidly to inward shifts.

As we can see from Tables 1 and 2 the estimate of the long-run PES of housing varies considerably across studies. However, excluding some earlier studies like Muth (1960) and Follain (1979), 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. We can conclude also by the recent studies that the PES of housing is higher in the USA comparing with UK, so the values should be different across countries. Another conclusion that can be made observing the results across studies is that the PES of housing varies at regional and local level, there are several studies that conducted this analysis and came to 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 econometric models used and with the specification. For example, the use of variables in differences seem to lead to lower values in the long-run PES of housing.

4 Determinants of housing supply

In the last two sections we revised the empirical studies but did not mention, in a systematic manner, the regressors of the housing supply models. However it is worthwhile to summarize the various categories of explanatory variables that have been used as well as the results that have been obtained. This will give us an overall picture of the results obtained in the existing empirical evidence.

The set of explanatory variables and the result regarding their impact on housing supply has varied across studies. Classifying the regressors in 8 categories, Table 3 shows selected references that include in their study that category of regressors.

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

Table 3: Selected references for each category of regressors.

Category of regressors	Selected References
Financing costs	Follain (1979);Topel and Rosen (1988);Dipasquale and Wheaton (1994); Blackley (1999); Mayer and Somerville (2000); Kenny (2003); Meen (2005); Hwang and Quigley (2006)
Construction costs	Follain (1979); Poterba (1984);Dipasquale and Wheaton (1992); Blackley (1999); Somerville (1999); Mayer and Somerville (2000); Kenny (2003); Meen (2005)
Vacancy rate	Leeuw and Ekanem (1971); Dipasquale and Wheaton (1992)
Sales delay	Topel and Rosen (1988); Mayer and Somerville (2000); Dipasquale and Wheaton (1994)
Inflation rate	Topel and Rosen (1988); Blackley (1999)
Stock of housing	Dipasquale and Wheaton (1994); Blackley (1999); Mayer and Somerville (2000)
Price of agricultural land	Dipasquale and Wheaton (1994); Blackley (1999)
Regulation	Pryce (1999); Hwang and Quigley (2006)

To have a more clear view of the sign and significancy of the regressors classified in the same categories of Table 3, we show in Table 4 the number of papers where that regressor has a positive and statistically significant impact, the number of papers where that regressor has a negative and statistically significant impact, and the number of papers where the regressor are not statistically significant.

In the category of financing costs, which includes the interest rate in various forms, almost all the empirical studies conclude that the cost of financing determines negatively the housing starts. This result is consistent with the theory. Levin and Pryce (2009) concludes that changes in the long-run real interest rate cause a low PES.

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 of them) are inconclusive. Although the expected negative impact is obtained if 5 articles, an equal number of papers shows a positive impact and in 2 other studies the construction costs are not statistically significant. As DiPasquale (1999) refers, most of the empirical literature on housing supply has the problem

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

Category of regressors	Positive	Negative	Not significant
Financing costs	–	9	1
Construction costs	5	5	2
Vacancy rate	–	2	1
Sales delay	–	3	–
Inflation rate	–	2	–
Stock of housing	1	2	2
Price of agricultural land	1	1	1
Regulation	–	2	1

of the measurement of construction costs. Thus one possible explanation for the inconclusive results is the quality of the data used to measure the variable. It is interesting to note that studies that use more disaggregated data, such as Somerville (1999), conclude that the variable has significant and negative impact on housing supply.

The evidence on the impact of the vacancy rate is scarce, since only 3 studies include this variable as a regressor. Two of this studies find a negative impact, which is accordance with theory, while one of the studies finds out that the variable is not statistically significant.

The variable sales delay is included only in three studies. However its impact on housing supply is negative and statistically significant in all the papers reviewed, which is theoretically consistent: if the houses take a very long time to sell the consequence is less housing starts. It is also worthwhile to note that the magnitude of the impact of sales delay is quite big in the three studies that include this variable.

The two studies that include inflation rate as a regressor, reveal 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: 2 articles reveal a negative impact, 2 studies show a non-significant impact and 1 study finds a positive impact. Similarly, the effect of the price of agricultural land is also

not clear as the three studies that include this variable reach completely different results.

In the category of regulation we include the planning controls, which is used in two papers. The reason why this type of regressor is not used more often is probably related with the lack of information, in particular it is difficult to have a time series regarding this variable. In theory, places where the regulatory controls are more restrictive have less housing starts, hence the sign of the coefficient should be negative. Two of the three studies that include regulation show the expected theoretical result whereas in one study the variable is not statistically significant. It is also important to mention that Green, Malpezzi and Mayo (2005) concludes that metropolitan areas that were more regulated have lower PES.

5 Strategic interaction models

In the three previous sections 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 want to review also the application of game theory/industrial organization to model housing supply. Unfortunately, has we will show, there are very few studies in this area.[1]

One of the most important application of game theory that we found was Baudewyns (2000). This article focus on the strategic interactions of land developers, analyzing the decisions made by two land developers that decide independently two variables: price and quality. He assumes that one firm is at the Central Business District (CBD) and builds houses in this location while the other builds in a more decentralized area. In his article, he considers a first stage in which the duopolists choose the level of housing quality, where the quality is defined as a function of accessibility and housing quality. In the second and last stage, the two firms simultaneously compete in prices to attract potential clients. Baudewyns 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 idea of the decentralized developer 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.

Ong, Sing and Choo (2004) apply a game theoretic Nash equilibrium approach to the issue of planning flexibility within the land use zoning. This work is based in the land use planning in

[1] Strategic interaction models have also been used in other related areas. For instance, Firoozi, Hollas, Rutherford, and Thomson (2006) present a game theoretic model of property tax assessment and provide evidence of asymmetric information in residential property assessments. Similarly, Anglin and Arnott (1991), analyze the terms of the brokerage contract between a house seller and his agent, applying the literature on the principal-agent problem.

Singapore, and in the example of the "white sites" programme in that country. The authors refer that flexibility in land use may be valuable, but it potentially introduces a supply inefficiency through the 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. The authors 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.

Wang and Zhou (2000), study one well documented problem in the real estate markets literature – the excess vacancy or overbuilding in the market. The article models overbuilding as a two-stage infinite-horizon non-cooperative game between land developers. The game is divided into two stages. 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. The authors conclude that it is natural to observe oversupply in real estate markets, developers have the incentive to build once they find a development opportunity. As consequence, developers as a whole, will supply more houses into the market than the level of demand. After the oversupply, developers will stop building until the demand absorb 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.

Chu and Sing (2007) incorporate strategic interaction in the modeling of optimal timing decision for real estate development projects. In their article they examine the subgame perfect equilibrium strategies for a duopoly real option model, with two firms with asymmetric demand functions. In the presence of preemptive threat, 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. So there are no relative advantages in the price function of the first mover over the next. Short bursts and recession induced overbuilding are two outcomes in the authors model. The model predicts that those two phenomena occur in earlier phases of market cycles, and not in the state of recession. In a recessed market with high volatility, the two firms will choose the waiting strategies.

Other important articles on housing supply examine the home building industry, its structure and industrial organization. Somerville (1999) states that his article is the first analytical treatment of the industrial organization of housing supply. He says that traditional studies of housing markets assume house building as a perfectly competitive industry. This study uses metropolitan area level data on the average size of homebuilder firms and homebuilder market concentration, to analyze the market structure of the industry. He concludes that there is a systematic variation across metropolitan areas on the housing market, this variation occurs in

the average size of builders and in the market share for the largest builders. So he argues that the results are more consistent with treating the industry as monopolistically competitive with a differentiated product. He also concludes that home builders 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. He argues that the type of regulating jurisdiction that establishes land-use regulation has influence on the builder size and market concentration.

Ball (2003) in his paper 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, housebuilding industrial structures vary considerably. Second, firms adopt strategies and they know, from experience, that they are important in determining profit. He states that strategic behavior can not have effect on market outcomes in a competitive model. The article analysis potential economies of scale, market factors, information asymmetries, regulation and risk. Ball argues that the great variety of ways in which housing is built, is not the reason that explain its industrial organization. Things like market instability, locational specificity, the markets where the houses are sold, information, strategic behavior, regulation in labour markets, land availability and the regulation, are factors that affect the size of firms. The author states also that strategic behavior is important in this industry, particularly through behavior with regard to the land market and residential development strategies.

6 Conclusion

Along the years, various empirical studies have been undertaken. Although there are some studies using cross section or panel data sets for metropolitan areas, the great majority of the studies use aggregated time series data. In spite of the differences regarding the type of data and econometric estimation methods, the main results are quite consistent across studies.

Excluding some earlier studies like Muth (1960) and Follain (1979), 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 price elasticity of 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 price elasticity of supply are higher in USA than in the UK.

Regarding the other determinants of housing supply, most empirical results are according

to the theoretical predictions. For instance, financial costs, inflation and sales delay influence negatively the housing supply. However there are also some results which are unexpected, namely the inconclusive results with respect to the impact of construction costs. One possible explanation for this inconclusive results is the difficulty in measuring accurately the construction costs.

Our review on the articles that use game theory/ industrial organization models of housing supply shows that the strategic interaction between land developers or constructors is still understudied and hence there is a lot of potential in exploring this type of models.

We believe that there is a need to increase our understanding of the behavior of constructors and land developers. This deeper understanding can come from the development of theoretical models predicting their decisions in a context where there exists strategic interactions between land developers and the estimation of empirical models based on micro data. Strategic interaction models of housing supply may allows us to understand how land developers make their decisions regarding the house location and house quality, may allow 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 contra-intuitive results such as those obtained with respect to the impact of construction costs.

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