1-2012

Supply Elasticity of Housing

Kyunghwan KIM
Sogang University

Sock-Yong PHANG
Singapore Management University, syphang@smu.edu.sg

Susan WACHTER
University of Pennsylvania

Published in International Encyclopedia of Housing and Home, 2012, Pages 66–74.
http://dx.doi.org/10.1016/B978-0-08-047163-1.00181-8

Supply Elasticity of Housing

Kyung-Hwan Kim, Sock-Yong Phang and Susan Wachter

Revised December 2010

1. Introduction

The supply elasticity of housing determines how quickly house prices respond to economic shocks and this has many real economic consequences. Malpezzi and Maclennan (2001) describes its importance in housing market analysis: 'most housing models, and most policy analysis hinge on explicit or implicit estimates of the price elasticity of supply of housing: does the market respond to demand side shocks with more supply or higher prices'. However, as pointed out by Quigley (1979), there exist real analytical difficulties in modeling the supply of housing. Attempting to measure the flow of housing services provided by the stock of housing is conceptually pleasing but hard to attempt. Moreover, there is no standard housing unit and each unit can vary considerably on many quality dimensions.

The heterogeneity of housing is further complicated by its durability as the supply of housing in each period is determined by production decisions for new units and also by decisions made by owners concerning conversion of the existing housing stock[1]. Construction of new housing in any given year typically represents a very small addition to the existing stock. Conversion of existing housing can include decisions for conversion to other use, demolition, abandonment, repair and renovation. In many of these decisions, the homeowner is both the supplier and the consumer, and consequently much of the literature on repair and renovation focuses on the demand for home improvement. Government policy, especially at the local level in the case of U.S., also impacts decisions on both new supply and conversion.

It is therefore not surprising to find the empirical work on housing supply to vary in estimation methods, data utilized, and results obtained. DiPasquale (1999) provides an exhaustive survey of the US literature on housing supply, whereas Bartlett (1989) compares U.S. and U.K studies and Bramley et.al. (1999) present reviews for a wider range of countries focusing on the private rental sector. The literature on housing supply since 2000 has grown considerably. Most of the empirical studies on housing supply relate to new construction, while the conversion of housing stock through renovation, repair and maintenance, have been much less studied. One major reason for such deficiency is the lack of micro data. Research in this area includes studies by Bodgon (1992), Potepan (1989) and Montgomery (1992).

2. Estimation methods

The estimation methods used in the studies of the determinants of housing supply may be categorized into the following approaches:

[1] Rydell (1982) estimates price elasticities for the repair (upgrading), inventory (new construction), and occupancy responses to demand shifts using U.S. data on services of rental housing. It also provides a review of earlier studies of supply elasticity.

(i) Reduced form estimation

Muth (1960), Follain (1979), Mayo and Sheppard (1996), Malpezzi and Mayo (1997), Malpezzi and Maclennan (2001), Meen (2002), Goodman (2005), Goodman and Thibodeau (2008) estimate reduced form models of housing markets to draw inferences regarding supply elasticity.

Following Malpezzi and Mayo (1997) and Malpezzi and Maclennan (2001), consider the following three-equation flow model of the housing market, with all variables in natural logarithms.

$$Q_D = \alpha_0 + \alpha_1 P_h + \alpha_2 Y + \alpha_3 D$$
$$Q_S = \beta_0 + \beta_1 P_h$$
$$Q_D = Q_S$$

The variables are defined as Q_D is the log quantity of housing demanded, Q_S is the log quantity of housing supplied, P_h is the log of the relative price per unit of housing, Y is the log of income, and D is the log of population.

The reduced form of the system can be found by equating demand and supply and solving for P_h, the price of housing.

$$P_h = \frac{\alpha_0 - \beta_0}{\beta_1 - \alpha_1} + \frac{\alpha_2}{\beta_1 - \alpha_1} Y + \frac{\alpha_3}{\beta_1 - \alpha_1} D$$

Making the reduced form stochastic,

$$P_h = \gamma_0 + \gamma_1 Y + \gamma_3 D + \varepsilon$$

The price elasticity of housing supply is estimated as

$$\beta_1 = \frac{\alpha_2}{\gamma_1} + \alpha_1$$

where γ_1 is the estimated elasticity of housing price with respect to income, and the parameters α_1, the price elasticity of housing demand and α_2, the income elasticity of demand, are parametrically assumed to lie in the interval -0.5 and -1 for α_1 and to be 0.5 and 1.0 for α_2. This approach is particularly useful in comparative studies of long run supply elasticity as the data requirements are relatively simple, comprising time series in housing prices, income and population. On the other hand, the accuracy of the estimates for supply elasticity depends on the specification of the reduced form house price equation and the estimates of the demand elasticities. It is utilized in Mayo and Sheppard (1996), Malpezzi and Mayo (1997), Malpezzi and Maclennan (2001), Goodman (2005), and Goodman and Thibodeau (2008)[2].

(ii) Structural approach

Other studies attempt to directly estimate housing starts or new housing construction in response to changes in housing price. Research based on this approach includes Poterba (1984), Topel and Rosen (1988), Follain, Leavens, and Velz (1993) and

[2] Goodmand and Thibodeau (2008) explicitly considers the user cost that links the rental price of housing services to the asset price of housing.

Meen (2005). Poterba (1984) takes an asset market approach and assumes that net housing investment depends on real house price, the real price of alternative investment projects, the construction wage rate, credit availability indicators, and interest costs. Topel and Rosen (1988) consider whether current asset prices are sufficient for housing investment decisions. They postulate that marginal costs rise with construction activity and builders lower costs by smoothing the increase in output over a number of periods. In their empirical work, they estimate a supply function where quarterly single family housing starts are a function of real house prices and a vector of cost shifters. Follain, Leavens and Velz (1993) estimate supply of multifamily housing where permits are a function of rents, the capitalization rate, replacement cost per unit of rental housing, and lagged permits. Meen (2005) estimates changes in housing starts as a function of their lagged values, the change in real interest rate and its lagged variables, and the difference between housing price and construction cost as well as its lagged variables.

The above models do not explicitly account for land as an input. The studies by DiPasquale and Wheaton (1994) and Mayer and Somerville (2000a) explicitly recognize the importance of the urban housing development process and land use regulation. DiPasquale and Wheaton (1994) estimate a stock adjustment model in which current starts are a function of the difference between desired stock and the stock in the previous period adjusted for removals. The current price level is used as a proxy for desired stock. The supply model estimated has single family starts as a function of current house prices, real short term interest rates, land costs as measured by the price of agricultural land, constructions costs measured as a weighted average of labor and material costs, and the stock of housing in the previous period.

Mayer and Somerville (2000b) developed a model of residential construction by extending the urban growth model presented in Capozza and Helsely (1989). Housing starts are modeled as a function of current and lagged changes in house price, real interest rates, and construction costs.

Green, Malpezzi and Mayo (2005) extend the work of Mayer and Somerville to derive the housing supply elasticity, η. For a monocentric city with a competitive land market, η is a function of city population size, n, and φ, a factor of proportionality that is decreasing in density. It is also affected by a discount rate, i, the city's population growth rate, g, transportation costs, k, and the price of housing, P, at a fixed point in the city.

$$\eta = [\,2 / (\varphi\sqrt{n})\,]\ [\,(i - g) / k\,]\ P$$

The intuition underlying this equation is that the factors affecting housing supply elasticity can be broken into components: the first bracket on the right hand side measures the size of the city, while the second bracket represents the city's expected growth rate relative to the discount rage (i-g) divided by the commuting cost, k. These factors account for how urban form will affect the property value as well as the discount rate that affects the valuation of the future price increases caused by city growth. Supply elasticity falls as the population and its growth rate rise, and as the interest rate and transport costs fall. Finally, these factors are scaled by the price of a housing unit that is similarly situated in different cities.

Green, Malpezzi and Mayo (2005) estimated supply elasticities for 45 US metropolitan areas and then analyzed their determinants by regressing the supply elasticities as a function of Metropolitan Statistical Area (MSA) population, population growth rate, average commuting time, population density and the level of house price. Buckley and Mathema (2008) obtained rough supply elasticity estimates for four African cities by plugging in estimates of the various components of the above equation.

In a recent careful study of major US metropolitan areas, Saiz (2010) uses GIS software and satellite-generated data on elevation and presence of water bodies to precisely estimate the amount of developable land. He found regulatory growth constraints and topographical land unavailability to be critical determinants of housing supply elasticity. Most areas that are widely regarded as supply-inelastic were found to be severely land constrained by their topography.

(iii) Error correction models

More recent papers on housing supply using US metropolitan data have utilized error correction methods that allow for adjustment dynamics or changing deviations from the equilibrium price. This approach is a neat way of combining long run relationships between variables with short run relationships between the first differences of the variables. The main motivation for many of these studies was to study short run housing price dynamics in order test for the efficiency of the housing asset market.

Abraham and Hendershott (1996) utilize this approach to first estimate equilibrium house price and then to calculate logarithmic differences from actual prices as a measure of disequilibrium. In a second stage, price changes are regressed as a function of construction costs, changes in employment and income, changes in the after-tax interest rate, and a disequilibrium measure constructed from the first stage estimates. Malpezzi (1999) estimated house price changes for 133 US metropolitan areas using a simple error correction formulation. He found faster growth of population and income to be associated with higher conditional price changes, suggesting a less than perfectly elastic short run housing supply.

Harter-Dreiman (2004) first estimate cointegrating equations and used price and income elasticity assumptions to derive ranges for the long run supply elasticity for 76 US MSAs. The residuals from the cointegrating equation are interpreted as the departure of the current level of prices from their long run equilibrium values. The residuals are then used in two equation vector error correction model of income and house price, an approach that incorporates intermetropolitan migration by allowing for endogenous income. The coefficient of the error correction term in the price equation provides information on the speed of adjustment from an unanticipated shock.

3. Empirical estimates of housing supply elasticity

As there are various approaches to estimate supply elasticity explained above, there is a wide range of elasticity estimates. Estimates for the same city for the same period can vary depending on the data used. The appendix table summarizes estimates of supply elasticity reported in the literature.

Empirical estimates of U.S. housing supply elasticity vary widely. Early estimates by Muth (1960) and Follain (1979) using national data suggest perfectly elastic housing supply. Stover (1986) finds the supply of single family houses in 61 metropolitan areas to be infinitely elastic. Rydell (1982) reports the long-run price elasticity for rental housing services of 11.5 and short-run elasticity ranging from 0.24 to 0.83. DiPasquale's 1999 survey of the literature concludes that estimates for new supply or starts lie between 3.0 and infinity. Blackley (1999) reports long run elasticities ranging from 1.6 to 3.7. Harter-Dreiman (2004) finds a supply elasticity between 1.4 and 3.2, nationally. Differentiating between new construction and stock, Mayer and Somerville's results suggest a price elasticity of starts at around 6.0 but a much lower stock elasticity of 0.08.

Studies of local supply elasticities using US MSAs data indicate significant geographical variations. Green, Malpezzi and Mayo (2005) estimate supply elasticities for 45 MSAs, and find the range to be between -0.30 (Miami) and 29.9 (Dallas). Goodman (2005) estimates central city and suburban housing market elasticities for 317 US suburban areas and reports that suburban supply is more elastic than central city supply. He provides the elasticity estimates between 1.25 and 1.42, with housing supplies more elastic (1.86) in the South and West than in the North and East (0.89). Goodman and Thibodeau (2008) report a mean of 0.62 for 95 MSAs with positive elasticities, with the largest elasticity of 1.38 in Charleston South Carolina. Saiz (2010) finds the price elasticity of 95 metropolitan areas in 2000 ranging from 0.60 to 5.45 with a population-weighted average of 1.75.

Models that allow for adjustment dynamics also show significant variations in the rate of adjustments to shocks. Mayer and Somerville (2000a) and Topel and Rosen (1988) suggest adjustment speeds of approximately one year using national data. Studies using MSA data such as Abraham and Hendershott(1996), Malpezzi (1999), and Harter-Dreiman(2004) find longer adjustment periods in the vicinity of 10 to 12 years.

The empirical literature on housing supply outside the US is small. Malpezzi and Maclennan (2001) compares the US and UK and show the UK to have less elastic supply. For prewar US, they estimate supply elasticities to be between 4 and 10 and for postwar, between 6 and 13. In contrast, UK estimates are found to lie between 1 and 4 for prewar and between 0 and less than 1 for postwar. Bramley (1993) estimates UK price elasticity of supply at about +0.31. Pryce (1999) estimates UK supply elasticity to be 0.58 in 1988 and 1.03 in 1992. Meen (2005) reports estimates for 9 English regions in the range of 0.0 and 0.84. Buckley and Mathema (2008) estimates for four African cities range from 0.43 for Accra to 2.83 for Dar es Salaam.

Using the reduced form method, Mayo and Sheppard (1996) and Malpezzi and Mayo (1997) compare estimates for US, Thailand, Malaysia and Korea. They found in general, Malaysia and Korea to have inelastic supply curves for housing, and Thailand and US to have elastic supply. They concluded that countries with more restrictive planning systems (Korea and Malaysia) have much smaller supply elasticities close to zero. These findings are consistent with those of Vermeulen and Rouwendal (2007) who find housing supply elasticity in the Netherlands owner-occupied sector to be close to zero both in the short and long run. Studies on Hong Kong (Tse, 1998 and Hui and Ho, 2003) also found no relationship between land supply and housing prices. Peng and Wheaton (1994) estimate price elasticity of supply of new units for Hong Kong to be approximately 1.1. Wang, Chan and Zheng (2010) report price elasticity for 35 Chinese cities in the range between 0.79 and 1.58.

4. Determinants of supply elasticity

Muth (1996) shows that the elasticity of housing services depends on the relative importance of land, the substitutability of non-land inputs for land, and the supply elasticity of developable land e_L. Assuming that the supply elasticity of non-land inputs is very large, the supply elasticity (e) can be expressed as

$$e= (k_N \Sigma + e_L)/ k_L$$

where Σ is the elasticity of substitution between land and non-land inputs, k_L is the share of land costs in total cost, k_N is the share of non-land costs in total cost, and k_L is the supply of developable land, which is affected by both natural and regulatory constraints.

A number of studies have attempted to explain the variations in housing supply elasticity across US MSAs. Saks (2008a) provides a recent survey of this literature and reviews the key factors that influence elasticity of housing supply. Saks attributes the secular decline in the elasticity of housing supply since the 1970s to three factors: structure construction costs, land availability and government regulation.

Research by Somerville (1999), and Gyourko and Saiz (2006) indicate that the response of housing supply to changes in physical construction costs is relatively elastic. Glaeser, Gyourko and Saks (2008) show that increases in these costs cannot account for the entire decline in residential construction activity in the past several decades.

The availability of land for new housing construction is also an important determinant of housing supply elasticity. Studies analyzing the effect of natural restrictions (topography, existence of bodies of water and geologic composition) on the supply of land include Rose (1989) and Saiz (2010).

The third factor influencing supply elasticity involves government regulation or permission to build. Regulatory practices that restrict new housing supply include growth controls such as green belts or urban growth boundaries, development moratoria, height and lot restrictions as well as zoning restrictions and historic preservation rules. Empirical research by Malpezzi (1996), Malpezzi, Chun and Green (1998), Quigley and Raphael (2005), Green, Malpezzi and Mayo (2005) and Saks (2008b) have found a strong correlation of land use regulation with higher house prices and less residential construction.

Comparative studies generally conclude that countries with more restrictive land use regulations and/or a high degree of government intervention in housing markets have reduced supply elasticities. Countries with a high degree of intervention on the housing supply side include Korea, Malaysia (Malpezzi and Mayo, 1997), the Netherlands (Vermeulen and Rouwendal, 2007), Hong Kong (Tse, 1998 and Hui and Ho, 2003) and UK (Evans and Hartwich, 2005)

Fu, Zheng and Liu (2008) examine population growth in 85 Chinese cities between 1998 and 2004, focusing on the determinants of housing supply elasticity. The findings indicate that elasticity depends on the availability of infrastructure, the cost of development, and the income inequality of the city, but not on population density. Kim, Malpezzi and Kim (2008) compute a composite index of property rights and regulation for 16 cities around the world and found a weak positive relationship between the index and house prices.

The durability of housing stock also means that elasticity of housing supply is asymmetric in response to increases versus decreases in demand. A decline in housing demand does not result in an immediate contraction of housing stock because housing depreciates slowly (Glaeser and Gyourko, 2005).

5. Implications of supply elasticity

The housing supply elasticity determines the level of house price and its variability when faced with a demand shock. For the same demand shock, a more elastic housing supply results in smaller price fluctuations, as compared to the case of an inelastic housing supply. Goodman and Thibodeau (2008) estimate housing supply elasticities for 133 US metropolitan areas from 2000 to 2005 and conclude that much of the large observed house price increases in the East Coast and in California owe much to inelastic supplies of owner-occupied housing. Malpezzi and Wachter (2005) develop a model that suggests that price volatility is strongly related to supply condition; and that the large impacts of speculation in real estate and boom-bust cycles are more likely when supply is inelastic.

Glaeser, Gyourko and Saks (2008) construct a model of housing bubbles and note that areas with inelastic supply had large price run-ups and subsequent long, drawn out crashes in two most recent episodes of housing bubbles. Another study by the same three authors (2006) indicate that differences in housing supply elasticity across cities also affect how cities respond to increases in productivity.

Housing supply elasticity also has implications for regional employment growth. The durability of housing when there is a persistent decline in housing demand results in low house prices relative to construction costs. This encourages households to remain in declining cities rather than move to a location with growing labor demand. The result is a process of slow and highly persistent urban decline (Glaeser and Gyourko, 2005). Saks (2008b) argues that because house prices influence migration, the elasticity of housing supply also has an important impact local labor markets. His empirical analysis using US MSA data showed that in the long run, an increase in labor demand results in considerably lower employment in metropolitan areas with a low elasticity of housing supply. Gyourko, Mayer and Sinai (2006) postulate that variations in housing supply elasticity also affect the distribution of income across and within cities. Supply restrictions that result in high house prices cause high income households to sort into metropolitan areas with highly valued amenities. The composition of the population is also affected as demographic groups with a high propensity to move relocate in response to rising house prices.

6. Topics for Future Research

In future research, it would be useful to tackle the complexity underlying the concept of housing supply with more rigor. Obvious issues include separating the role of land, neighborhood quality, and the physical structure in the supply of generic "housing." Increasing data availability may make identification of the separable components of housing supply increasingly possible. In addition, going forward it may be possible to identify and model renovations and repairs as significant sources of housing supply, along with new production. Relying primarily on estimates from the Census Bureau's Value of Private Construction Put in Place (C-30), Harvard's Joint Center for Housing Studies (Bendimerad 2008) produces the Leading Indicator for the Remodeling Industry (LIRA), a moving four-quarter rate of change estimate of current and future home improvement expenditures by homeowners. Integrating the analysis of these data together with new supply dynamics will be of interest. More broadly the contribution of land price dynamics to overall housing supply may be further subject to monitoring and analysis through local data collection. Advances in the collection of data, particularly public data, allow analysis to be performed with unprecedented geographic detail. (Case Western's Northeast Ohio Community and Neighborhood Data for Organizing and the Reinvestment Fund's Policy Map are two notable examples.) Nonetheless, the cost of such data is often high, leaving it to private firms and resource-pooling institutions to develop accessible data inventories.

The role of the supply elasticity as a driving factor underlying the recent house price boom and bust has raised the visibility of this issue considerably. Nonetheless the literature may be attributing excessive importance to variations in the housing supply elasticity and too little to the variability in the formation of house price expectations – bubbles – and the variability in risk premiums. Implicitly the primacy of the role of supply elasticity may be based in part on the simplistic and highly questionable assumptions that the risk premium is constant and that we can measure expected house price inflation. In fact the user cost and risk premium may be themselves subject to greater volatility in inelastic housing supply regimes thus complicating the identification of the role of limited housing supply from that of temporary shifts in user costs due to heightened price expectations or temporarily reduced risk premia during price run-ups. Levin and Pryce (2009) show that a decline user costs (the real interest rate) can lead to inelastic supply. The literature on this is currently being extended to cycles and the procyclicality of lending in real estate and macro cycles as part of the dialogue on systemic risk and the role of real estate (Pavlov and Wachter, 2011).

Finally, the rapid growth of recent literature on housing supply poses a challenge of keeping up. A modest take away from the list of references is a sharp migration of some of the newer literature from the more traditional academic outlets for housing research into a broader array of outlets. In light of the proprietary databases and new broader-based interest from the private sector in housing prices, establishing a repository of the expanding literature might provide a valuable public good.

Bibliography

1. Abraham, J.M. and Hendershott, P.H. 1996. Bubbles in metropolitan housing markets. *Journal of Housing Research* 7, 191-207.

2. Bartlett, W. 1989. *Housing supply elasticities: Theory and measurement.* York: Joseph Rowntree Memorial Trust Working Paper 2.

3. Blackley, D. M. 1999. The long run elasticity of new housing supply in the United States: empirical evidence for 1950-1994. *Journal of Real Estate and Financial Economics* 18, 25-42.

4. Bendimerad, A. 2008. Developing a Leading Indicator for the Remodeling Industry. Joint Center for Housing Studies, Research Note N07-1. Harvard University.

5. Bodgon, A.S.1992. The determinants of homeowner expenditures for renovation, alteration and repair. Ph.D. dissertation, Harvard University.

6. Bramley, G. 1993. Land use planning and the housing market in Britain – the impact on house building and house prices. *Environmental Planning A* 25, 1021-1052.

7. Bramley, G., Satsangi, M., and Pryce, G. 1999. *The supply responsiveness of the private rented sector: an international comparison*. London: Department of the Environment, Transport and the Regions.

8. Buckley, R.M. and Mathema, A. 2008. Real Estate Regulations in Accra: Some Macroeconomic Consequences? *Urban Studies* 45, 2249-2281 Capozza, D.R. and Helsely, R.W.1989. The fundamentals of land prices and urban growth. *Journal of Urban Economics* 26, 295-306.

9. DiPasquale, D. 1999. Why don't we know more about housing supply? *Journal of Real Estate and Financial Economics* 18, 9-23.

10. DiPasquale, D. and Wheaton, W.C. 1994. Housing market dynamics and the future of housing prices. *Journal of Urban Economics* 35, 1-27.

11. Evans, A.W. and Hartwich, O.M. 2005. *Unaffordable housing: fables and myths*.

London: Policy Exchange.

12. Follain, J.R. 1979. The price elasticity of the long run supply of new housing construction. *Land Economics* 55, 190-199.

13. Follain, J.R., Leavens, D.R., and Velz, O.T. 1993. Identifying the effects of tax reform on multifamily rental housing. *Journal of Urban Economics* 34, 275-298.

14. Fu, Y., Zheng, S. and Liu, H. 2008. Population growth across Chinese cities: Demand shocks, housing supply elasticity and supply shifts. http://ssrn.com/abstraact=1153022.

15. Glaeser, E.L. and Gyourko, J. 2005. Urban decline and durable housing. *Journal of Political Economy* 113, 345–375.

16. Glaeser, E.L. Gyourko, J. and Saks, R.E. 2006. Urban growth and housing supply. *Journal of Economic Geography* 6, 71-89

17. Glaeser, E.L., Gyourko, J. and Saks, R.E. 2008. Housing supply and housing bubbles. Working Paper 14193, Cambridge, MA: NBER.

18. Goodman, A.C. 2005. The other side of eight mile: suburban population and housing supply. *Real Estate Economics* 33, 539-569.

19. Goodman, A.C. and Thibodeau, T.G. 2008. Where are the speculative bubbles in US housing markets? *Journal of Housing Economics* 17, 117-137.

20. Green, R., Malpezzi, S. and Mayo, S. 2005. Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources. *AEA Papers and Proceedings* 95, 334-339.

21. Gyourko, J., Mayer, C. and Sinai, T. 2006. Superstar cities. Working Paper No. 12355. Cambridge, MA: NBER.

22. Gyourko, J. and Saiz, A. 2006. Construction costs and the supply of housing structure. *Journal of Regional Science* 46, 661–680.

23. Harter-Dreiman, M. 2004. Drawing inferences about housing supply elasticity from house price responses to income shocks. *Journal of Urban Economics* 55, 316-337.

24. Hui, E.C. and Ho, V.S. 2003. Does the planning system affect housing prices? Theory and with evidence from Hong Kong. *Habitat International* 27, 339-359.

25. Kim, K.H., Malpezzi, S. and Kim, C.H. 2008. *Property Rights, Regulations and Housing Market Performance*. Korea: Center for Free Enterprise and Friedrich Naumann Foundation for Liberty.

26. Levin, E. and Pryce, G. 2009. What Determines the Price Elasticity of House Supply? Real Interest Rate Effects and Cyclical Asymmetries, *Housing Studies* 24, 713-736.

27. Malpezzi, S. 1996. Housing prices, externalities, and regulation in U.S. metropolitan

areas. *Journal of Housing Research* 7, 209–241.

28. Malpezzi, S. 1999. A simple error-correction model of house prices. *Journal of Housing Economics* 8, 27-62.

29. Malpezzi, S., Chun, G. and Green, R. 1998. New place to place housing indexes for U.S. metropolitan areas, and their determinants: an application of housing indicators. *Real Estate Economics* 26, 235-275.

30. Malpezzi, S. and Maclennan, D. 2001. The long run price elasticity of supply of new residential construction in the United States and the United Kingdom. *Journal of Housing Economics* 10, 278-306.

31. Malpezzi, S. and Mayo, S. 1997. Getting housing incentives right: a case study of the effects of regulation, taxes and subsidies on housing supply in Malaysia. Land Economics, 73, 372-391.

32. Malpezzi, S. and Wachter, S. 2005. The role of speculation in real estate cycles. *Journal of Real Estate Literature* 13, 143-164.

33. Mayer, C.J. and Somerville, C.T. 2000a. Land use regulation and new construction. *Regional Science and Urban Economics* 30, 639–662.

34. Mayer, C.J. and Somerville. C.T. 2000b. Residential Construction: Using the Urban Growth Model to Estimate Housing Supply. *Journal of Urban Economics* 48, 85-109.

35. Mayo, S. and Sheppard, S. 1996. Housing supply under rapid economic growth and varying regulatory stringency: an international comparison. *Journal of Housing Economics* 5, 274-289.

36. Meen, G. 2002. The time series behavior of house prices: a transatlantic divide. *Journal of Housing Economics* 11, 1-23.

37. Meen, G. 2005. On the Economics of the Barker Review of Housing Supply. *Housing Studies* 20, 949-971

38. Montgomery, C.1992. Explaining home improvement in the context of household investment in residential housing. *Journal of Urban Economics* 32, 326-350.

39. Muth, R. 1960. The demand for non-farm housing. In Harberger, A.C. (ed.) *The Demand for Durable Goods*. Chicago: University of Chicago Press, 27-96.

40. Muth, R. 1996. Theoretical issues in housing market research. In Arnott, R(ed.) *Encyclopedia of Economics Volume 1, Regional and Urban Economics Part 2*. The Netherlands: Harwood Academic Publishers.

41. Pavlov A. and Wachter, S. 2011. *Subprime Lending and Real Estate Prices*. Real Estate Economics, 39, forthcoming.

42. Peng, R. and Wheaton, W. 1994. Effects of restrictive land supply on housing in Hong Kong: an econometric analysis. *Journal of Housing Research* 5, 263-291.

43. Potepan, M.J.1989. Interest rates, income, and home improvement decisions. *Journal of Urban Economics* 25, 282-294.

44. Poterba, J.M.1984. Tax subsidies to owner occupied housing: an asset market approach*.* *Quarterly Journal of Economics* 99, 729-752.

45. Pryce, G. 1999. Construction elasticities and land availability: a two-stage least squares model of housing supply using the variable elasticity approach. *Urban Studies* 36, 2283-2304.

46. Quigley, J.M.1979. What have we learned about urban housing markets? In Mieszkowski, P. and Straszheim, M. (eds.) *Current Issues in Urban Economics* (pp. 391-429). Baltimore: John Hopkins University Press.

47. Quigley, J.M. and Raphael, S. 2005. Regulation and the high cost of housing in California. *AEA Papers and Proceedings* 95, 323-328.

48. Rose, L. 1989. Urban land supply: natural and contrived restrictions. *Journal of Urban Economics* 25, 325–45.

49. Rydell, C.P. 1982. Price Elasticities of Housing Supply. The Rand Corporation, Santa Monica, CA.

50. Saiz, A. 2010. The Geographic Determinants of Housing Supply. *Quarterly Journal of Economics*, 125, 1253 - 1296.

51. Saks, R.E. 2008a "Housing supply." *The New Palgrave Dictionary of Economics Online*. Second Edition. Eds. Steven N. Durlauf and Lawrence E. Blume, Basingstoke, Hampshire; New York: Palgrave Macmillan.

52. Saks, R.E. 2008b. Job creation and housing construction: constraints on metropolitan area employment growth. *Journal of Urban Economics* 64, 178-195.

53. Somerville, C.T. 1999. Residential construction costs and the supply of new housing: endogeneity and bias in construction cost indexes. *Journal of Real Estate Finance and Economics* 18, 43–62.

54. Stover, M. 1986. The Price Elasticity of the Supply of Single-Family Detached Urban Housing. *Journal of Urban Economics* 20, 331-340.

55. Topel, R. and Rosen, S. 1988. Housing investment in the United States. *Journal of Political Economy* 96, 718-740.

56. Tse, R.Y. C. 1998. Housing price, land supply and revenue from land sales. *Urban Studies* 35, 1377-1392.

57. Vermeulen, W. and Rouwendal, J. 2007. Housing supply and land use regulation in the Netherlands. Tinbergen Institute Discussion Papers 07-058/3, Tinbergen Institute.

58. Wang, S. Chan S H, and Zheng, S. 2010. Housing Supply Elasticity across Chinese Cities, Their Determinants and Impact on Housing Prices, mimeo.

Table: Estimates of supply elasticity from selected studies

Authors	Data Used	Dependent Variable	Estimation Method	Supply Elasticity Estimates
Blackley (1999)	US AA, 1950-1994	real residential construction	RFE, SA, ECM	in levels 1.6-3.7, in difference: 0.8
Harter-Dreiman (2004)	US 76 MSAs AA, 1980-1998	log house price level and personal income level	ECM	
Green, Malpezzi, and Mayo (2005)	US 44 MSAs AA, 1979-1996	number of housing units	SA	-0.3to 29.9
Goodman (2005)	US 317 Suburban AD, 1970, 1980, 1990	log difference in housing value and rents and in housing quantity	RFE	1.25-1.42
Goodman and Thibodean (2008)	US 133 MSAs AA, 1990, 2000	log difference in housing value and rents and in housing quantity	RFE	0.35 (mean)
Malpezzi and Maclennan (2001)	US and UK AA, 1850-1995(UK); 1889-1994(US)	log relative price of new residential construction	RFE	Flow model: US Pre-war: 4-10, Post war: 6-13; UK Pre-war: 1-4, Postwar 0-1. Stock adjustment model: US: 1-6; UK 0-1.
Pryce (1999)	UK 162 LA districts AD, 1988, 1992	private housing starts		boom:0.58, slump:1.03
Buckley and Mathema (2008)	4 African cities, city-wide level data	log of household expenditure on housing and services	RFE, SA	Addis Ababa: 1.25, Accra: 0.43, Nairobi: 0.94, Dar es Salaam: 2.83
Mayo and Sheppard (1996)	Malaysia(1972-1986), Thailand(1970-1986), and Korea(1970-1985) AA	log of housing price index	RFE	Malaysia: 0-1.5, Thailand: infinite, Korea: 1-1.5
Malpezzi and Mayo (1997)	Malaysia, Thailand, Korea, and US AA, 1970-1986	log of the relative price per unit of housing	RFE	Malaysia: 0-0.35, Thailand: infinite, Korea: 0-0.17, US: 12.59-19.88
Vermeulen and Rouwendal (2007)	Netherlands AA, 1970-2005	volume of residential investment, new construction for total housing market, new construction for owner-occupier sector	SA	close to 0 both in the short and long run
Tse (1998)	Hong Kong AA, 1976-1995	house price index; land supply		no relationship between land supply and housing prices
Hui and Ho (2003)	Hong Kong AQ, 1988-2004	housing price	RFE	no relationship between land supply and housing prices
Peng and Wheaton (1994)	Hong Kong AA, 1965-1990	real private housing price; number of new units in private sector	SA	1.1
Malpezzi (1999)	US 133 MSAs AA, 1979-1996	annual real change in house price	ECM	less than perfectly elastic short-run housing supply
Muth (1960)	US national AA 1915-1934	price of housing	RFE	perfectly elastic
Follain (1979)	US national AA 1947-1975	price of housing	RFE	perfectly inelastic
Poterba (1984)	US national AA, 1963-1982	net investment in structures	SA	0.5-2.3
Stover (1986)	US 61 metropolitan areas, 1976-81 cross section	cost of housing		infinite supply elasticity
Topel and Rosen (1988)	US AQ 1963 I-1983 I	single-family housing starts	SA	long-run: 3.0, short-run: 1.0
DiPasquale and Wheaton (1994)	US AA 1963-1990	single-family housing starts	SA	elasticity of desired stock: 1.2-1.4, elasticity of construction: 1.0-1.2
Follain, Leavens, and Velz (1993)	Atlanta, Chicago, Dallas, and Oakland AQ, 1977-1990	multifamily housing permits	SA	3.0-5.0
Mayer and Somerville (2000b)	US AA 1975-1994	single-family housing starts	SA	elasticity of starts: 6.3, elasticity of stock: 0.08
Meen (2005)	UK AQ1973-2002	housing starts	SA	0.0-0.84
Wang, Han, Zheng (2010)	China 35 cities AA 1988-2008	price of housing	RFE	0.79-1.58

NOTE: (Data Used) AD: aggregate data; AA: aggregate annual data; AQ: aggregate quarterly data.
(Estimation Method) RFE: reduced form estimation; SA: structural approach; ECM: error correction methods