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ABSTRACT

Previous empirical investigations provide evidence of substantial regional variation in the supply elasticity of housing, and show that the elasticity and its variation across cities within the U.S. are significantly influenced by regulatory supply constraints, city level population, population density, and geographic constraints. This paper studies empirically if these findings apply to a country that is notably different from the U.S. with respect to its population density, typical city size, geographic and cultural coherence, and regulatory constraints, i.e., Finland. Based on data for the period 1987-2011, our findings are largely in line with those reported for the U.S. The results support the theoretical models indicating that the supply elasticity is largely a local phenomenon, i.e., dependent mainly on city specific factors rather than the abundance of undeveloped land at the country level. The long-term supply elasticity substantially varies across Finnish cities. The city size, zoning policies, and geographic constraints are found to be the most important factors causing regional elasticity differences, accounting for some 80% of the elasticity variation.

JEL Classification: R31, R52
Keywords: housing; supply; price; elasticity; regions

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1 Introduction

The price elasticity of supply of housing is a key factor in the housing market. It determines the capability of housing supply to respond to changes in housing demand, and therefore the extent to which increasing housing demand induces higher housing prices or greater housing stock. Hence, the supply elasticity has considerable consequences for households and firms, and thereby for the performance of cities and for the economy as a whole. In particular, by causing greater cost of housing for households, lower supply elasticity has notable impacts on the population growth and composition, income growth, income and wealth distribution, migration, and on local labor markets (Glaeser et al., 2006; Saks, 2008; Zabel, 2012; Gyourko et al., 2013). Moreover, less elastic housing supply strengthens housing price cycles (Malpezzi and Wachter, 2005; Goodman and Thibodeau, 2008; Glaeser et al., 2008) which, in turn, can amplify cycles in the overall economy. Since more inelastic housing supply decreases the attractiveness of a city from both firms' and households' point of view hindering the growth of the city, and amplifies housing price cycles, more elastic housing supply can generally be seen as a desirable aim.[1]

Many commentators, including some economists, often argue that in a country with an abundant reserve of vacant developable land, housing supply should be very elastic – after all, land availability should not restrict housing construction, as land is not a scarce resource. This is also the case in Finland, which is one of the most sparsely populated developed countries and where even the largest urban area is small in world standards. It is usual to hear claims that the high housing price level in the Helsinki area, by far the largest urban area in the country, must be mostly due to inefficient zoning practices and ineffective land policies, since the surroundings of the city are rich of undeveloped land that is suitable for housing development and because such land is relatively plentiful even within the borders of the city. What about the other cities that are much smaller than Helsinki and surrounded by vast areas of agricultural land and forests – surely housing supply should be close to perfectly elastic in these areas, at least in the absence of artificial regulatory constraints, it is argued.

Based on the theory, these commentators are missing the point: There are many other factors than the availability of vacant land and regulatory restrictions that are expected to significantly influence the housing price level and elasticity of housing supply in a city (e.g. Capozza and Helsley, 1989; Green et al., 2005). The urban economics theory also implies that the supply elasticity is largely a

[1] Local authorities may also have some incentives to restrict housing supply, though (e.g. Quigley and Rosenthal, 2005; Koster et al., 2012).

local phenomenon, i.e., dependent mainly on city specific factors rather than the abundance of undeveloped land at the country level. In accordance with the theoretical considerations, empirical research provides evidence of greater city population and population density decreasing the supply elasticity in the U.S. MSAs (Saiz, 2010; Paciorek, 2013). Rose (1989) and Saiz (2010) further show that water bodies can have considerable influences on the supply elasticity. The careful empirical investigation of Saiz (2010) adds topographical constraints in the list of factors affecting the elasticity. In line with the theory, previous empirical findings also indicate that the supply elasticity of housing can significantly vary across regions (e.g. Goodman and Thibodeau, 2008; Saiz, 2010; Caldera and Johansson, 2012).

The U.S. is in many ways notably different from a country such as Finland, however. In addition to being more sparsely populated, Finland is a country with considerably smaller cities than those in the U.S.: while even Helsinki is small relative to a typical U.S. MSA, the second to tenth largest cities in Finland have populations ranging from less than 250,000 to approximately 80,000. Furthermore, Finland is geographically and culturally a much more coherent country than the U.S., and the regulatory constraints in Finnish cities are typically strict. This raises the question of whether the previous empirical findings hold for a country like Finland, or whether the supply elasticity does not notably vary across Finnish cities and if it does, whether the variation is almost solely due to differences in the city level regulatory constraints.

Due to the importance of the elasticity regarding not only housing economics but also urban economics and urban decision-making in general, empirical research on the theme has substantially increased during the last decade. As Gyourko (2009) states, “Research on housing supply has grown owing to improved data combined with heightened interest in policies such as local land use regulations.” Nevertheless, empirical research on the extent to which various factors cause regional elasticity differences is very limited. Indeed, while the investigation of regional elasticity differences and its determinants has concentrated on the U.S. and U.K., a very densely populated country, there does not appear to be similar examinations using regional level data for a country such as Finland. Therefore, the statement by Cheshire and Sheppard (2004) according to which “understanding the variety of ways in which housing supply responds to land use regulation, and empirical measurement of the magnitude of these responses is an important area for future research” still holds today.

This study aims to contribute to filling the gap in empirical examination of regional variation in the price elasticity of housing supply and its determinants. In addition to focusing on a small sparsely populated country, this appears to be the first investigation on the theme using city level data for a European market. Finland also provides a good standpoint for empirical research because of the extensive and reliable data on Finnish urban housing markets. Besides examining whether the theoretical considerations and previous empirical implications apply to Finland, our aim is to investigate if the arguments according to which possible regional elasticity differences are a consequence of variations in the regulatory constraints only hold true.

In the methodological side, the paper has three contributions to the literature. First, we show how the Johansen Maximum Likelihood cointegration technique can be used to estimate long-run elasticity values. Second, this technique allows us to use stock data rather than flow data. It is well known that, in time series analysis, information is lost when differenced (i.e. flow) variables are used instead of the levels (stock). This is the case, in particular, when the aim is to examine long-term dynamics. In previous empirical studies, the supply elasticity estimates are modelled based on housing starts, newly completed construction or change in the housing stock, or indirectly utilizing a housing price equation. Third, we use recursive analysis to investigate whether there have been notable changes in the elasticities over time. As far as we know, recursive analysis to study the temporal variation has not been conducted in earlier literature. The recursive analysis helps to conclude whether the estimated elasticity values are relevant still in today's environment.

We use quarterly data for 15 Finnish cities for the period 1987-2011 to estimate directly the long-term dependence of overall housing supply on the housing price level. We concentrate on the *long-term* elasticity, as it is the factor that essentially determines how various regional variables react to different economic shocks, such as productivity shocks, over the long horizon. Generally, the *short-term* elasticity notably differs from the long-term one, as housing supply adjusts only sluggishly. After estimating the supply elasticities, we examine the factors behind the observed regional differences. For that purpose, we construct an index to measure the regulatory constraints for housing supply in a similar manner to Gyourko et al. (2008). We also add demographic variables and variables aiming to capture the geographic supply restrictions in the cross-section estimations investigating the key determinants of elasticity variations across cities.

The results show that supply elasticity can considerably vary across cities even in a much smaller, more sparsely populated, and more coherent country than the U.S. The long-run elasticity estimates vary between 0.2 and 0.8, i.e., housing supply is far from perfectly elastic. The stability of the elasticities over the sample period cannot be rejected based on recursive analysis. In line with the previous findings for the U.S., both regulatory and geographic constraints are significant contributors to the elasticity and its regional variation. Despite the small number of cross-sectional observations these constraints, together with city size, are statistically significant explanatory variables for the elasticity, and account for some 80% of the observed elasticity variation across cities. The notable regional elasticity variation and the importance of city size in the cross-section models are in line with the theoretical models of housing supply which indicate that the supply elasticity is a local phenomenon: Despite the large land reserves in the country, it is the city size and availability of developable residential land within the city that essentially determine the elasticity. The results further indicate that, while more flexible regulation can obviously increase the supply elasticity, the possibilities of local regulation to influence the elasticity are limited despite the abundance of vacant developable land in the country.

The next section presents a brief theoretical discussion on the determination of the price elasticity of housing supply. The previous empirical literature is reviewed in section three. Sections four and five describe the empirical methodology and data used in the study, respectively. Empirical findings are reported in section six, after which the study is concluded.

2 Theoretical considerations

In an extension of a model developed by Mayer and Somerville (2000a), Green et al. (2005) derive the following formula for the price elasticity of housing supply to examine regional variation of the elasticity:

$$e = \left(\frac{2}{\phi\sqrt{n}}\right) \frac{\lambda - g}{k} p. \quad (1)$$

Equation (1) shows that the elasticity (e) is adversely influenced by greater population of the city (n), population density (ϕ is a factor of proportionality that is increasing in density), growth rate for the city (g), and transportation costs (k). The elasticity is increased, in turn, by higher after-tax cost of capital (λ), and the house price level (p denotes the price level at some fixed point in the city). Intuitively, equation (1) shows that the key factors determining the supply elasticity can be broken down into components (Kim et al., 2012). The term in brackets measures the impact of the size of the city, and ($\lambda - g / k$) is the city's expected growth rate relative to the discount rate, divided by the cost of commuting. Finally, the first two factors are scaled by the price of a housing unit that is similarly situated in different cities.

The model assumes circular city without geographical or regulatory constraints for supply, and competitive markets. Therefore, even in the absence of differences in regulatory and geographical restrictions for housing supply, the elasticity is expected to vary across cities. It is widely agreed, however, that the regulatory and geographic constraints can have considerable influences on the supply elasticity (Green et al., 2005; Saks, 2008; Saiz, 2010; Hilber and Robert-Nicoud, 2013; Paciorek, 2013). Thus, the city level elasticity can be presented as a function of the variables in (1) plus the constraints set by regulation (R) and geography (G):

$$e = f(n, \phi, \lambda, g, k, p, R, G), \quad (2)$$

where the expected sign is negative for n, ϕ, g, k, R, and G, and positive for λ and p. Regulatory constraints that restrict new housing construction contain zoning restrictions including height and lot limits, growth controls such as green belts and urban growth controls, development moratoria, and historic preservation rules (Kim et al., 2012). Geographic constraints, in turn, compose of natural restrictions such as bodies of water and topography (Saiz, 2010). Importantly, equations (1) and (2) imply that the elasticity is determined, to a major extent, by city level factors, and we should expect this to hold for any country regardless of the nationwide population density and land abundance. Note also that within-city regulation differences can have different effects from those caused by between-city regulation variations (Koster et al., 2012). This study concentrates on exploring the between-city differences in regulation and supply elasticity of housing.

3 Previous empirical findings: supply elasticity and its implications

3.1 Supply elasticity estimates

Kim et al. (2012) divide the estimation methods in the studies estimating housing market supply elasticities into three categories: reduced form approach, structural approach, and error-correction models. In the reduced form approach, the supply elasticity is estimated indirectly based on an estimated equation for housing price. The supply estimates are dependent on the specification of the reduced form price equation as well as on the estimates for demand elasticities. This methodology is used e.g. by Malpezzi and Mayo (1997), Buckley and Mathema (2008), and Goodman and Thibodeau (2008).

In the structural approach, instead, the supply elasticity is estimated directly by including a housing supply variable as the dependent variable in the estimated model. The supply variable is typically either housing starts or new completed construction. The explanatory current and lagged variables used in these models include housing price variables, construction costs, variables measuring the opportunity cost of capital, and credit availability indicators (Poterba, 1984; Mayer and Somerville, 2000a, 2000b; Green et al., 2005; Meen, 2005; Wang et al., 2012; Paciorek, 2013).

The error-correction framework, in turn, allows for the investigation of the adjustment dynamics of housing supply. Indeed, the main aim of many of the studies utilizing the error-correction methodology is to examine the short-term housing market dynamics rather than to estimate long-term elasticity measures. Studies using the error-correction framework include Abraham and Hendershott (1996), Malpezzi (1999), and Harter-Dreiman (2004). Harter-Dreiman (2004) utilizes a long-term cointegrating equation estimated in an (vector) error-correction framework to derive long-term supply elasticities for the U.S. MSAs. Her technique to estimate the long-term elasticities can also be regarded as a reduced form approach because of the indirect estimation of the elasticities through a price equation.

The empirical estimates reported in the literature show considerable variation.[2] While the notable differences in the estimates are partly due to actual significant regional differences and differences over time, part of the variation can most likely be attributed to the different estimation approaches. Most studies focus on the U.S. market. DiPasquale (1999) reviews earlier literature concluding that the estimates for housing starts or new supply vary between inelastic (i.e. less than unity) and infinity in the U.S. Blackley (1999), in turn, finds the elasticities to range from 1.4 to 3.2 at the national level. Green et al. (2005) and Saiz (2010) report substantial differences in the MSA specific elasticities, the range being from –0.30 to 29.9 in the former and from 0.60 to 5.45 in the latter analysis. In Goodman and Thibodeau (2008), the largest MSA level elasticity estimate is 3.0, while the mean across cities is 0.35 (0.62 for the MSAs with a positive elasticity estimate). Paciorek (2013), in turn, finds elasticities to range between 1.7 and 2.8 in the ten largest MSAs.

The empirical literature using data for other countries is quite small. The findings by Mayo and Sheppard (1996) and Malpezzi and Mayo (1997) suggest that supply is more inelastic in Malaysia and Korea than in the U.S. and Thailand. Malpezzi and Maclennan (2001) and Ball et al. (2010) report lower supply elasticity for the U.K. than for the U.S. The postwar estimates for the U.K. are

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[2] Kim et al. (2012) provide a more detailed list of the empirical studies on the supply elasticity: the data used, estimation methods, and the elasticity estimates.

particularly small, between zero and one (Malpezzi and Maclennan, 2001). Ball et al. (2010) further find the long-run elasticity to be even greater in Australia than in the U.S. Caldera and Johansson (2013) find substantial differences across a set of 21 OECD countries. They report the smallest elasticity (0.15) for Switzerland and the highest elasticity for the U.S. (2.0). The elasticity estimates for European countries are generally – in 13 out of 15 cases – smaller than one. For Finland, they report an estimate of 0.99.

At the regional level, Meen (2005) reports long-run supply elasticities to vary between 0.0 and 0.8 in the U.K, and the estimations of Buckley and Mathema (2008) imply notable elasticity differences across four African cities. The panel analysis of Wang et al. (2012), in turn, shows substantial elasticity variation across 35 Chinese cities, the lowest of the reported elasticities being below one and the largest as high as 37.

In sum, at the country level the elasticity has been generally found to be greater in the U.S. than in the other countries, except for Australia. In the more recent literature, the typical reported estimates are in the range 0.1 – 6 depending on the region.

3.2 Determinants and implications of supply elasticity variations across regions

Empirical research on the determinants of cross-sectional differences in the elasticity is still scarce. Studies that show an adverse impact of tighter regulatory constraints on the elasticity within the U.S. include Malpezzi et al. (1998), Mayer and Somerville (2000b), Green et al. (2005), Quigley and Raphael (2005), Saks (2008), Saiz (2010), and Paciorek (2013). In Green et al. (2005), the factors that explain statistically significantly the elasticity variation across cities also include city size and growth, and housing price level. The coefficients on city size and housing price have unexpected signs, though. The authors state that simultaneity is certainly an issue in the estimations. Another potential factor causing the unexpected signs is multicollinearity between the explanatory variables. Rose (1989), Saiz (2010), and Paciorek (2013), in turn, show that geographic constraints, in addition to regulatory restrictions, affect land supply and thereby housing supply and prices. While Rose (1989) considers the role of water bodies, Saiz (2010) provides the first study that investigates carefully the role of both water systems and topography. Paciorek (2013) also finds that higher density lowers the elasticity.

Literature on the determinants of regional supply differences is particularly scarce outside the U.S. While all the studies mentioned in the preceding paragraph focus on the U.S. market, Meen and

Nygaard (2011) examine two areas of England, the Thames Gateway and the Thames Valley, showing that natural and man-made geographic constraints (water bodies, green space, gardens) lead to less development. Malpezzi and Mayo (1997) report lower supply elasticities for the countries with a higher degree of government intervention / regulation, and Caldera and Johansson (2013) find supply elasticities to be generally greater in the more densely populated countries and in countries with longer waiting time to get building permits.

While it is evident that lower housing supply elasticity causes higher housing prices, *ceteris paribus*, recent research has highlighted several other consequences of inelastic housing supply. Malpezzi and Wachter (2005) and Paciorek (2013) show that lower elasticity increases housing price volatility thereby having adverse influence on the stability of the overall economy. In line with these studies, Glaeser et al. (2008) present a model of housing bubbles that predicts the regions with more elastic housing supply to have fewer and shorter bubbles, with smaller price increases. They further show that the price run-ups of the 1980s in the U.S. were almost exclusively experienced in cities where housing supply is relatively inelastic. Nevertheless, they conclude that the welfare consequences of bubbles may be greater in the more elastic places because those places will overbuild more in response to a bubble.

Glaeser et al. (2006) demonstrate how a positive productivity shock is more likely lead to notable population growth in areas with relatively elastic housing supply. In the low supply elasticity regions, in contrast, such a shock results in smaller growth in population but greater increases in the levels of income and housing prices. Saks (2008) argues that the supply elasticity has an important impact on local labor markets through its influence on migration. He shows empirically that an increase in labor demand leads to considerably smaller employment growth in the low supply elasticity areas than in the high elasticity cities, in the long run. Zabel (2012), too, presents evidence of housing supply elasticity notably affecting cross-city migration and the labor market. According to Gyourko et al. (2013), regional variations of housing supply also affect the distribution of income and the composition of population within and across cities. Finally, Paciorek (2013) considers the wealth transfer consequences of low supply elasticity. He concludes that incumbent homeowners gain in the expense of prospective future home buyers in the low elasticity areas, as lower elasticity induces higher housing price growth when demand for housing increases. He also notes the adverse influence of greater housing price volatily, induced by lower supply elasticity, on homeowners.

4 Empirical model and methodology

To estimate the long-term price elasticity of housing supply for each city, this study uses the structural estimation approach. That is, the elasticity parameter is estimated directly using an equation that includes housing supply. Contrary to previous studies on the theme, our estimates are based on the actual housing stock instead of a flow variable. The quarterly flow variables often do not cater for the time-taking adjustment of supply, but rather measure the short-term supply response to price changes. Moreover, it is well-known that differencing of data, corresponding here to the use of supply flow variables and price changes instead of the levels, causes loss of information by ignoring the information contained in the levels. This is the case especially when the aim is to investigate the long-term dynamics. Therefore, the use of overall level of supply to estimate a long-term equilibrium model for housing stock and thereby the supply elasticity is well-reasoned.

Some elasticity estimates reported in the literature are based on two observation dates only. While two distant observation dates may give enough information to estimate the average long-term elasticity, the use of time series including numerous observation periods has advantages over the 'two-date approach'. In particular, time series analysis allows for diagnostic specification checks on the estimated model – both w.r.t. the variables included in the model and the temporal stability of the elasticity.

Following the theoretical framework of DiPasquale and Wheaton (1992), we include housing price level, construction costs, and the interest rate in the model determining the level of housing supply. There has been a fairly high degree of agreement that these are the key determinants of housing supply, and a number of previous empirical studies use price, construction cost, and cost of debt variables in an equation for housing supply growth or for housing starts (e.g. Mayer and Somerville, 2000a, 2000b; Meen, 2005). Housing supply is expected to be positively affected by the price level and adversely affected by greater construction costs and higher interest rates.

As the variables are non-stationary (see Table 1), we use the Johansen (1996) Maximum Likelihood method to estimate the long-term elasticities. The Johansen method is suitable for non-stationary variables that are cointegrated, and the Johansen Trace test enables a formal test for cointegration, i.e., for stationary long-term relation(s) between the variables. Since the price level and construction costs can be endogenous w.r.t. supply, another attractive feature of the Johansen method is that it is not vulnerable to endogeneity. To the best of our knowledge, this is the first study that uses the

Johansen method to estimate long-term supply equations and thereby to derive the long-term elasticity estimates. We use the following conventionally used Vector Error-Correction Model (VECM) to study the long-term relationship between the variables:

$$\Delta X_t = \mu + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_{k-1} \Delta X_{t-k+1} + \alpha\beta' X_{t-1} + D_t + \varepsilon_t, \quad (3)$$

where ΔX_t is $X_t - X_{t-1}$, X_t is a four-dimensional vector of the values of the stochastic variables, i.e. housing stock (s), housing price (p), construction costs (c), and interest rate (i), and $t = 1,\ldots,T$. Γ_i is a 4 x 4 matrix of coefficients for the lagged differences of the stochastic variables at lag i, k is the number of lags of differenced variables included, μ is a four-dimensional vector of intercepts, D_t denotes a (s-1)-dimensional vector of centered seasonal dummies (in this study $s = 4$, since quarterly data are used), ε_t is a four-dimensional vector of white noise error terms, and α is a vector (or a matrix in case r > 1) containing the speed of adjustment parameters.

Of main interest in this study is $\beta' X_{t-1}$, as this part forms the long-term model in levels, β being a vector (or a matrix in case r > 1) of long-term coefficients for s, p, c, and i. Having four non-stationary variables, $\beta' X_{t-1}$ can include up to three stationary long-term equations (i.e. cointegrating equations/vectors). The selection of the number of cointegrating equations (r) is done by comparing the estimated Bartlett small-sample corrected Trace test statistics, proposed by Johansen (2002), with the quantiles approximated by the gamma distribution (see Doornik, 1998).

Of the potentially several long-term relations we are interested in one, namely the long-term equilibrium relation for housing supply.[3] To qualify for such a relation, a stationary linear combination among the variables has to be one that includes the supply and towards which supply adjusts. Given that the interest rate is often found to be (at least) close to stationary, detecting r = 2 (the maximum r found in this study) may be due to the mean-reverting nature of the interest rate. That is, despite finding i non-stationary based on the DF-GLS unit root test, the second stationary vector suggested by the Trace test can include the interest rate alone. Furthermore, as the interest rate tends to be mean-reverting and close to stationary, it can be expected that it has only short-term relevance regarding housing supply. Therefore, we use the Likelihood Ratio (LR) test to investigate whether the interest rate can be excluded from the long-term equation for supply and, in the case of

[3] There also are techniques, such as Fully-Modified OLS, that allow for the estimation of single equation cointegrating models with a preset dependent variable. However, there are several reasons to use the Johansen method here: it allows for a formal recursive investigation of the stability of the long-term relation(s) and for testing of weak exogeneity. Moreover, the Johansen technique avoids the two-step complication present in the residual-based single-equation cointegration tests, and caters for the short-term dynamics of the system. Finally, small-sample corrected test values are available for the Trace test and for the Likelihood Ratio test for model restrictions, to increase the efficiency of the tests.

r =2, whether supply, price, and construction costs can be excluded from the second long-term vector.

Most convincing evidence of being a long-term equation for supply is provided if it is only supply that reacts to deviations from the equilibrium, i.e., if the other variables are weakly exogenous. Hence, we use the LR test to examine the validity of the following restrictions on the error-correction mechanism $\alpha\beta' X_{t-1}$ (β_{jd} and α_{jd} denote the long-term coefficient and speed of adjustment coefficient for variable *j* in the *d*th cointegrating equation, respectively):

If r = 2, H^1_0: $\beta_{i1}, \beta_{s2}, \beta_{p2}, \beta_{c2} = 0$.

If H^1_0 is accepted, we conclude that one of the two stationary relations is due to the interest rate, set r = 1, and proceed to the hypothesis testing for the case r = 1. Indeed, in all the three r = 2 cases H^1_0 is accepted.

If r = 1, H^2_0: $\alpha_{p1}, \alpha_{c1}, \alpha_{i1}, \beta_{i1} = 0$.

In case the LR test rejects H^2_0, we loosen the restrictions to allow for the inclusion of the interest rate in the long-term equation:

H^3_0: $\alpha_{p1}, \alpha_{c1}, \alpha_{i1} = 0$.

If either H^2_0 or H^3_0 is accepted and supply adjusts towards the estimated long-term relation, then the equation can clearly be interpreted as a long-term equilibrium relationship for supply, and we normalize the cointegrating vector on housing supply. Then, by moving the other variables to the right-hand side, we get the desired form for the long-term supply equation:

$$s_t = \mu + \beta_p * p + \beta_c * c \ (+ \beta_i * i), \quad (4)$$

where the parameter of interest is β_p, the long-term price elasticity of housing supply, and μ is a deterministic constant. To investigate the stability of the estimated relation over the sample period, we conduct the forward and backward recursive Max Test (in the R-form) presented in Juselius (2006).

Note that in this analysis the Trace test, LR tests and recursive analysis work above all as diagnostic checks for the specification of the long-term equation. Finally, in (3), the lag length is selected based on the Hannan-Quinn information criteria (HQ). However, more lags are included if the Lagrange Multiplier test at lag length two indicates residual autocorrelation.

The elasticity estimates are used in a cross-section analysis investigating the determinants of elasticity differences across cities. The cross-section analysis is conducted using the Ordinary Least Squares (OLS) estimation technique.

5 Data

5.1 Supply elasticity estimations

We use quarterly data for the period 1987-2011 to estimate the price elasticity of housing supply for 15 Finnish cities. These cities include the ten largest ones in Finland and some other regional centers. The data used in the study are provided by Statistics Finland unless mentioned otherwise. For housing supply and prices, the data are based on the city level administrational boundaries. These boundaries are used instead of some wider geographic measure for an urban area, since in Finland the regulatory constraints, such as land policy practices and rules, are to a large extent set at the city level and apply within the boundaries of each city only. Furthermore, in Finland neighboring municipalities do not generally form contiguous urban structures (an exception is the Helsinki area).

We measure housing supply as the overall housing stock, in square meters, within the boundaries of a given city. The data on the overall housing stock are at annual frequency. We estimate the quarterly changes in the stock based on the city level completed construction data from 1994 onwards and on the national level construction data for the early sample period. The construction data are available at the quarterly frequency. This should yield good approximations for the quarterly variations in the stock. In any case, the quarterly movements are of minor relevance here, as they should not have notable influence on the estimated *long-term* parameters.

The city level quarterly hedonic housing price indices for privately financed apartments and townhouses are used to measure the housing price development. These two dwelling types account for a great majority of housing stock in each of these cities. There are good reasons to focus on the privately financed sector: In Finland, privately financed housing can be bought, sold and rented at market prices without any restrictions, whereas selling prices and rental prices are controlled in the publicly regulated (i.e. subsidized) sector. Furthermore, the data consist of apartments and townhouses, since data on these dwelling types are more reliable than data on single-family housing: In Finnish cities, single-family housing is a substantially more heterogenous group in its characteristics than the other housing types, and the market for single-family housing is considerably thinner than that for other housing types. That is, the use of apartment and townhouse data diminish the heterogeneity problem that is associated with housing price data even when hedonic indices are employed.

The interest rate and construction cost series are nationwide, as there are no regional series for these variables. This should not be a notable problem, since the interest rate variation across cities is negligible and because great differences in the evolution of construction costs over time are unlikely in a relatively small and coherent country such as Finland, where the same construction companies operate regardless of the region. As Saiz (2010) states, the prices of capital and materials are determined at the national or international level, and construction is an extremely competitive industry with an elastic labor supply. Moreover, the claim according to which differences in construction cost development are insignificant is consistent with previous research (Gyourko and Saiz, 2006).

Unlike the other data used to estimate the elasticities, the interest data are provided by the Bank of Finland. The interest rate is measured as the quarterly average lending interest rate of deposit banks and other credit institutions in Finland for corporate loans during 2003-2011, after tax. For 1987-2002, the interest rate series is back-casted using the changes in the average lending interest rate for the overall lending stock of the same banks and institutions, as data on the corporate loan interest rate are available only for the late sample period.

All the above mentioned variables, except for housing supply, are deflated by the cost of living index. That is, all the right-hand side variables in (4) are in real terms. Furthermore, natural logs of all the variables except for the interest rate are used, and seasonally desmoothed series is employed for the interest rate. Based on the DF-GLS unit root test, all the variables are I(1), i.e., non-stationary in levels but stationary in differences (Table 1).

Table 1 DF-GLS unit root test statistics

City	*Housing supply*		*Housing price*	
	Level (lags)	Growth (lags)	Level (lags)	Growth (lags)
Espoo	.75 (2)	−6.72** (1)	−.99 (1)	−5.25** (0)
Helsinki	.41 (4)	−3.37** (4)	−.89 (1)	−4.27** (0)
Jyväskylä	.24 (2)	−2.68** (1)	−1.56 (2)	−3.89** (1)
Kajaani	.76 (2)	−3.54** (1)	−.67 (0)	−2.60** (3)
Kotka	.89 (3)	−7.84** (0)	−1.57 (3)	−2.46* (2)
Kuopio	.37 (4)	−3.43** (1)	−1.35 (3)	−2.50* (3)
Lahti	1.25 (2)	−6.87** (0)	−1.53 (2)	−2.74** (2)
Oulu	.26 (4)	−3.89** (1)	−1.09 (2)	−3.28** (1)
Pori	1.52 (1)	−5.76** (0)	−.55 (0)	−3.56** (2)
Rovaniemi	.80 (2)	−3.07** (1)	−.59 (0)	−8.89** (0)
Tampere	.11 (4)	−2.17* (3)	−1.27 (2)	−2.99** (1)
Turku	.47 (4)	−3.26** (4)	−1.43 (2)	−3.66** (1)
Vaasa	1.28 (2)	−8.22** (0)	−.04 (0)	−2.55* (3)
Vantaa	.37 (2)	−2.40* (1)	−1.59 (1)	−3.99** (0)
Construction costs	−0.99 (1)	−5.99** (0)		
Interest rate	−1.04 (0)	−7.50** (0)		

* and ** denote statistical significance at the 5% and 1% level, respectively. The lag length is decided based on Schwarz Information Criteria.

A potential complication with the time series data described above is that for many cities the geographic boundaries have somewhat changed during the sample period. We compute the city level series based on the 2008 city boundaries. Another potential complication is the influence of subsidized housing construction. In case the scale of subsidized construction has substantially varied over time, the supply elasticity, too, may have experienced changes. This is the case especially if the crowding-out effect of subsidized construction on non-subsidized construction is relatively small. Recent evidence shows that the crowding-out effect can be very large, i.e., that the impact of subsidized construction on the overall housing stock can be small (Eriksen and Rosenthal, 2010). Anyhow, because the changes in the administrational boundaries and in the role of subsidized construction, as well as other institutional changes (in taxation, for instance) may have induced structural changes in the parameters in (4), we check the stability of the estimated long-term relations over time as described in the previous section.

5.2 Cross-section analysis

The variables used to study the key factors causing the regional elasticity differences include all the factors in (2) except for the transportation costs and after-tax cost of capital. The after-tax interest rate variation across Finland is negligible, i.e., the cost of capital cannot explain any observed elasticity differences. Transportation costs are not included, since reasonable data for that variable are not available. In a paper including transportations cost variable in a similar analysis, the variable is found to be highly insignificant (Green et al., 2005). To be consistent with the elasticity estimations, the variables included in the cross-section analysis are based on the 2008 city boundaries.

Our population measure is the average population during 1987-2008, while population density is defined as the total number of inhabitants divided by the land area (km^2) within the city boundaries as of 2008. The annualized change in population during 1987-2008 is used to measure the city growth rate. There are no data for all the cities to measure the housing price level in a similar location, such as the city center. Therefore, our proxy for p in the cross-section analysis is the average per square meter transaction price of privately financed apartments during 1987-2008.[4]

In Finland, the land use policies are set, to a large extent, by local governments at the municipality level. In this sense, Finland is largely similar to California (Quigley and Raphael, 2005). Therefore, there can be significant variation in the regulatory constraints of housing supply across Finnish cities. We follow Gyourko et al. (2008) and use a survey method to construct an index aiming to measure the city level regulatory constraints of housing supply. The index is based on interviews of key personnel responsible for land policy actions in each city. The interviews include a number of questions aimed to capture differences in the zoning and other land policy rules across cities. Of the questions used by Gyourko et al. (2008) in their survey regarding the U.S. MSAs, we select those that are relevant in the Finnish context and alter these questions to suit better the Finnish system. The length of the interviews varied between 45 and 105 minutes, and all the interviews were recorded and transcribed. The transcriptions were sent to the interviewees by email to give them the opportunity to correct possible mistakes and misunderstandings.

We divide the questions into two categories measuring the regulatory constraints: zoning policies, and (other) land policies.[5] We then give a score in the range 1-5 for each city for each question, 5 indicating the most flexible regulatory environment. Based on these scores, we compute an index value for the two sub-categories as an average of the scores for questions regarding each category. The questions also include one that aims to measure the scale of geographic constraints faced by the

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[4] The case of Helsinki region is different from the other Finnish cities in the sense that Helsinki and its surrounding cities of Espoo and Vantaa together form a larger urban area. While the regulatory constraints are set at the city level, it is clear that the population of Helsinki alone would understate housing demand pressure in Helsinki, i.e., in the central city of the larger urban area. Therefore, we use the population of the whole Helsinki metropolitan area as the population measure for Helsinki. The choice between the population of Helsinki or of the whole area affects the parameter estimates only slightly.

[5] In this article, the term ‘zoning’ refers to land use planning procedures and practices, while ‘land policy’ refers to policies supporting land use planning, such as policies guiding the selection of areas for land use planning and the role of the city as a landowner and developer.

city. An overall ‘supply constraint index’ value for each city is calculated as an average of three index values: zoning policy, land policy, and geographic constraints. The questions based on which the indices are constructed are presented in the Appendix B.

Although the above described index includes an estimate for the geographic constraints, we also add another, quantitatively more formal, measure of geographic restrictions in the analysis. Following Saiz (2010), this variable shows the share of area within 5-kilometer radius of each city center that is not developable due to water bodies (sea, lakes, and rivers). As the Finnish cities are considerably smaller than the U.S. MSAs, we use a much smaller radius than Saiz (2010) does. Since Espoo and Vantaa do not have one prominent center but they have multiple smaller centers rather, we specify the share of water bodies slightly differently for those cities. For Espoo, we compute the water share within 3-kilometer radius from four regional centers (Espoo center, Leppävaara, Matinkylä, and Tapiola). For Vantaa, in turn, we calculate the water bodies within 4-kilometer radius from the center of Tikkurila and 3-kilometer radius from the center of Myyrmäki.

Saiz (2010) also caters for topography in his analysis. Unfortunately, we do not possess data on topography. In any matter, Finland is a very flat country where the role of topography on housing development is only small. In contrast, the restrictive role of water bodies is significant in many cases, as many of the cities are located next to the sea and the inland cities are often located on lakeshore (in some cases even surrounded by lakes). Indeed, the highest share of water bodies is as high as 52%, in Kotka, while the mean share across the cities is 23%. The two geographic constraint measures are not necessarily mutually exclusive in the cross-section modelling, since they can embody information that is not contained in the other variable: while the water share variable caters for one aspect regarding geographic constraints, the local experts can have knowledge on some other geographic impediments on housing supply.

6 Empirical findings

6.1 Supply elasticity estimates

Table 2 summarizes the Johansen Maximum Likelihood estimation results. For three cities, the Trace test suggests two cointegrating relations. In all these cases H^1_0 is accepted, i.e., the other relation includes the interest rate only. There also are three borderline cases, Espoo, Pori and Rovaniemi, regarding the hypothesis r=0, i.e., no cointegrating relations among the variables. Given that the small-sample correction decreases the power of the Trace test, as a trade-off for the improved size properties of the Trace test, and that the other statistics for these cities are reasonable – in particular, the supply adjusts significantly towards the estimated long-term relation and these relations appear to be stable over time – we proceed assuming that also these long-term relations are reasonably well specified.

The most notable exception to the general rule of detecting one cointegrating vector in the system including supply, price level, construction costs, and interest rate is Turku, where the system is non-invertible. Therefore, the supply elasticity for Turku is estimated indirectly based on the income elasticity of supply and income elasticity of housing prices (see the Appendix A). The estimated elasticity is well in line with that of the other cities. Anyhow, the results in the cross-section analysis are similar regardless of the inclusion of Turku.

For the remaining eight cities, the test statistics support the existence of one cointegrating vector. H^2_0 is accepted in all but one case: for Espoo, the interest rate cannot be excluded from the long-run equilibrium, but H^3_0, i.e. the weak exogeneity restriction, is accepted.[6] In all the cases, the stability of the long-term relation over the sample period is accepted based on the recursive analysis implying that the estimated values are relevant still in today's environment.

The second column in Table 2 reports the point estimates for supply elasticities. The elasticities are generally between 0.4 and 0.7, the variation being from 0.20 in Helsinki to 0.82 in Rovaniemi. While Rovaniemi is a small inland city of around 50 000 inhabitants without notable geographic constraints, Helsinki has about ten times (the whole metro area about twenty times) the population of Rovaniemi and is located next to the sea making the land availability much more restricted.

Even though the regional variation is notable, it is smaller than the regional elasticity differences reported for the U.S. (Green et al., 2005; Goodman and Thibodeau, 2008; Saiz, 2010). This is not unexpected given that Finland is a much smaller and geographically and culturally more coherent country than the U.S. Furthermore, the elasticity estimates for Finnish cities are relatively small compared with those generally reported for the U.S. This may be explained, at least partially, by the relatively strict Finnish land use regulations. Our estimates are in line with recent findings of Caldera and Johansson (2013), according to which the supply elasticity generally is below one in European countries, while it is substantially greater in the U.S.

[6] The Oulu model does not include the interest rate, as the model is not invertible if the interest rate is present. That is, for Oulu $H^2_0 : \alpha_{p1}, \alpha_{c1} = 0$.

Table 2 Johansen cointegration test results and estimates for the price elasticity of housing supply

Region	Price elasticity of supply	Trace test, p-value			LR test on H^1_0, p-value	LR test on H^2_0, p-value	LR test on H^3_0, p-value	Lags in differences
		r=0	r≤1	r≤2				
Espoo	.405 (.251)	.12	.53	.23		.	.47	2
Helsinki	.202 (.064)	.02	.18	.31		.93		3
Jyväskylä	.697 (.220)	.06	.14	.66		.59		1
Kajaani	.653 (.232)	.04	.14	.30		.41		1
Kotka	.531 (.186)	.06	.36	.39		.14		1
Kuopio	.295 (.138)	.01	.05	.25	.43	.27		3
Lahti	.540 (.157)	.02	.13	.17		.24		1
Lappeenranta	.660 (.137)	.05	.13	.15		.72		3
Oulu	.747 (.197)	.05	.45	.49		.95		2
Pori	.579 (.180)	.14	.28	.35		.13		3
Rovaniemi	.817 (.278)	.11	.33	.59		.26		1
Tampere	.373 (.100)	.04	.09	.65	.17	.34		3
Turku	.538							
Vaasa	.622 (.120)	.00	.02	.25	.71	.35		4
Vantaa	.508 (.102)	.00	.24	.43		.69		1

The cities are ordered alphabetically. Standard errors for the elasticity estimates are shown in the parenthesis. The reported Trace test and LR test values are Bartlett small-sample corrected (except for the Trace test for Vaasa, as the correction is not available if the lag length is greater than three). The lag length is selected by the Hannan-Quinn Information Criteria together with the Lagrange Multiplier test for residual autocorrelation at lag length two. The estimations for Turku are reported in the Appendix A.

6.2 Factors explaining the elasticity variation across cities

The variables included in the cross-section analysis investigating the determinants of regional elasticity differences are presented in Table 3. The low part of the table also shows correlations between the variables. All the variables show substantial variation across cities. The supply constraint index is the highest, i.e., the supply constraints are the smallest, in Oulu (4.33) – a city that is well known in Finland of its successful zoning and land policies[7] – and the lowest in Espoo (2.39), a city that is known for its wealthy population, restrictive land policies, and problematic land ownership structure. The sub-indices, too, notably vary. The extreme case concerning the geographic constraints index is Kuopio that is surrounded by lakes from practically all directions. The elasticity of housing supply is positively and significantly correlated with the supply constraint index and all its sub-indices, as expected. Regarding the sub-indices, by far the greatest correlation is that between the geographic constraints and the elasticity. Also expectedly, the elasticity has a significant negative correlation with population and population density, and with the share of water bodies. The housing price level, in turn, is negatively correlated with the regulatory and geographic restriction indices. The other correlations, too, are logical. Interestingly, the zoning sub-index is not significantly correlated with either the land policy or geographic constraints indices. In line with the theoretical considerations and empirical findings of Saiz (2010) concerning the U.S., city population is not significantly correlated with geographic constraints. Finally, the negative correlation between city size and regulatory strictness is worth noting: regulation is stricter in the greater cities. Figures 1 and 2 further illustrate the relationship of the elasticity with the city size and the supply constraint index. Note that the non-linear relation is stronger between the elasticity and population than a linear one.

[7] For instance, the city of Oulu coordinates land transactions and provides incentives for early land sales and development, thereby diminishing incentives for strategic behavior – pointed out by Menezes and Pitchford (2004) – that hinders new housing development.

Table 3 Values for the variables used in the cross-section analysis

Region	*Supply elast.*	*Supply constr. index*	*Subind.: zoning*	*Subind.: land policy*	*Subind.: geogr.*	*Pop.*	*Pop. growth*	*Pop. density*	*House price*	*Water bodies*
Helsinki	.202	2.46	2.38	3.00	2.00	908,016	0.8 %	3051.0	1,932	49.7 %
Espoo	.405	2.39	2.50	2.67	2.00	202,335	2.2 %	762.5	1,600	13.8 %
Tampere	.373	2.83	2.50	4.00	2.00	188,945	1.1 %	397.1	1,175	40.5 %
Vantaa	.508	2.49	3.13	2.33	2.00	171,854	1.5 %	800.1	1,308	1.0 %
Turku	.538	2.56	3.00	2.67	2.00	168,019	0.4 %	713.6	1,055	5.1 %
Oulu	.747	4.33	4.00	4.00	5.00	115,122	1.9 %	356.4	1,046	18.2 %
Lahti	.540	3.81	3.75	3.67	4.00	96,099	0.3 %	735.3	917	13.1 %
Kuopio	.295	2.71	3.13	4.00	1.00	87,379	0.6 %	81.2	1,092	43.8 %
Jyväskylä	.697	3.92	3.75	4.00	4.00	76,976	1.2 %	806.8	1,100	17.7 %
Pori	.579	3.58	3.75	4.00	3.00	76,378	–0.1 %	147.5	826	3.1 %
Lappeenranta	.660	3.96	2.88	4.00	5.00	57,701	0.3 %	77.9	1,055	28.3 %
Rovaniemi	.817	4.07	2.88	4.33	5.00	56,460	0.6 %	7.76	850	13.8 %
Vaasa	.622	3.29	2.88	4.00	3.00	55,853	0.4 %	307.3	999	34.3 %
Kotka	.531	2.76	3.63	2.67	2.00	55,669	–0.3 %	201.8	797	52.2 %
Kajaani	.653	4.26	3.13	4.67	5.00	39,075	–0.1 %	20.7	818	7.8 %
CORRELATIONS										
Elasticity	1									
Constr. index	.838***	1								
Zoning	.508*	.525**	1							
Land policy	.482*	.790**	.180	1						
Geography	.845***	.944**	.352	.639**	1					
Population	–.656***	–.482*	–.493*	–.391	–.354	1				
Pop. growth	–.125	–.218	–181	–.353	–.151	.352	1			
Pop. density	–.586**	–.444*	–.358	–.465*	–.317	.954***	.272**	1		
Price	–.680***	–.596**	–.608**	–.495*	–.442*	.851***	.598**	.841***	1	
Water	–.526**	–.434	–.327	–.136	–.470*	.387	–.191	.287	.248	1

The cities are ordered by the size of the market. *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively. Higher index value indicates smaller supply restrictions. Population is measured as the average number of inhabitants during 1987-2008, and population density as population per land area km^2 in 2008. House price is the average transaction price level (€/m^2) during 1987-2008. For Helsinki, the population is that of the whole metropolitan area.

Figure 1 City size and the supply elasticity

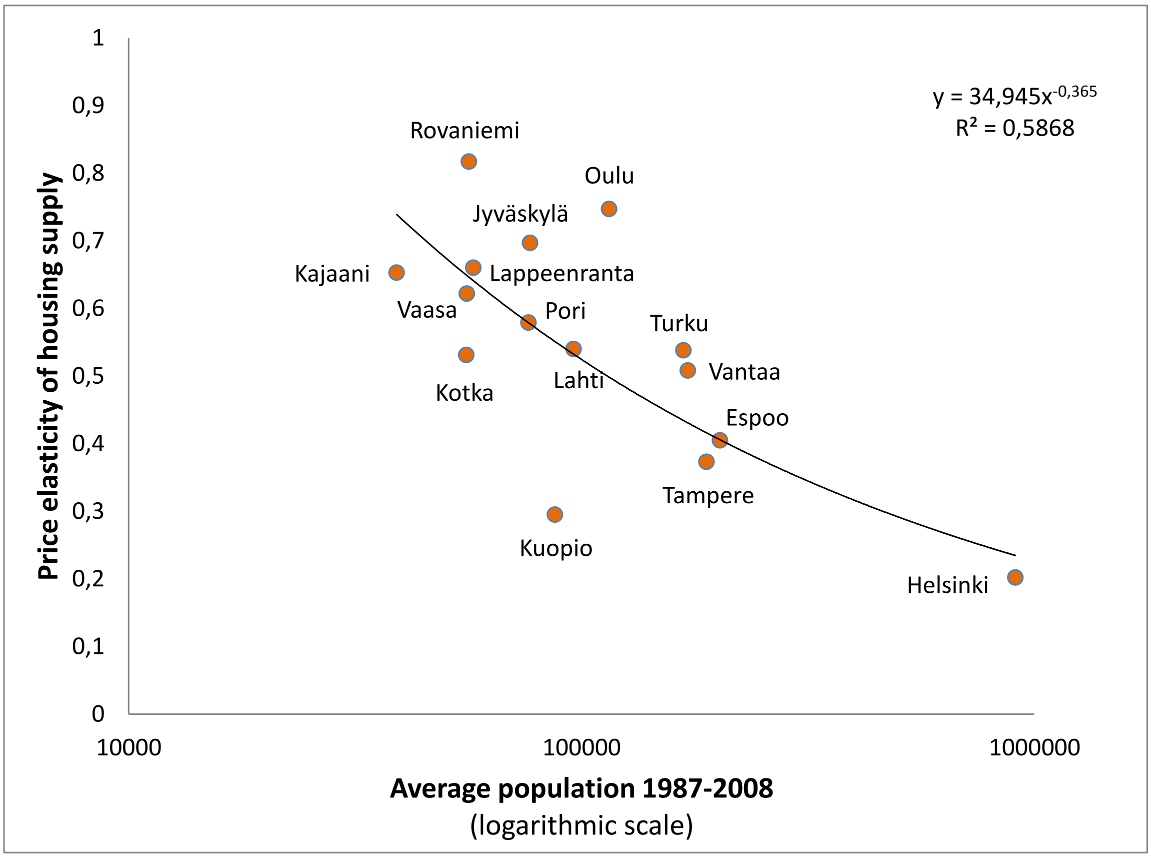
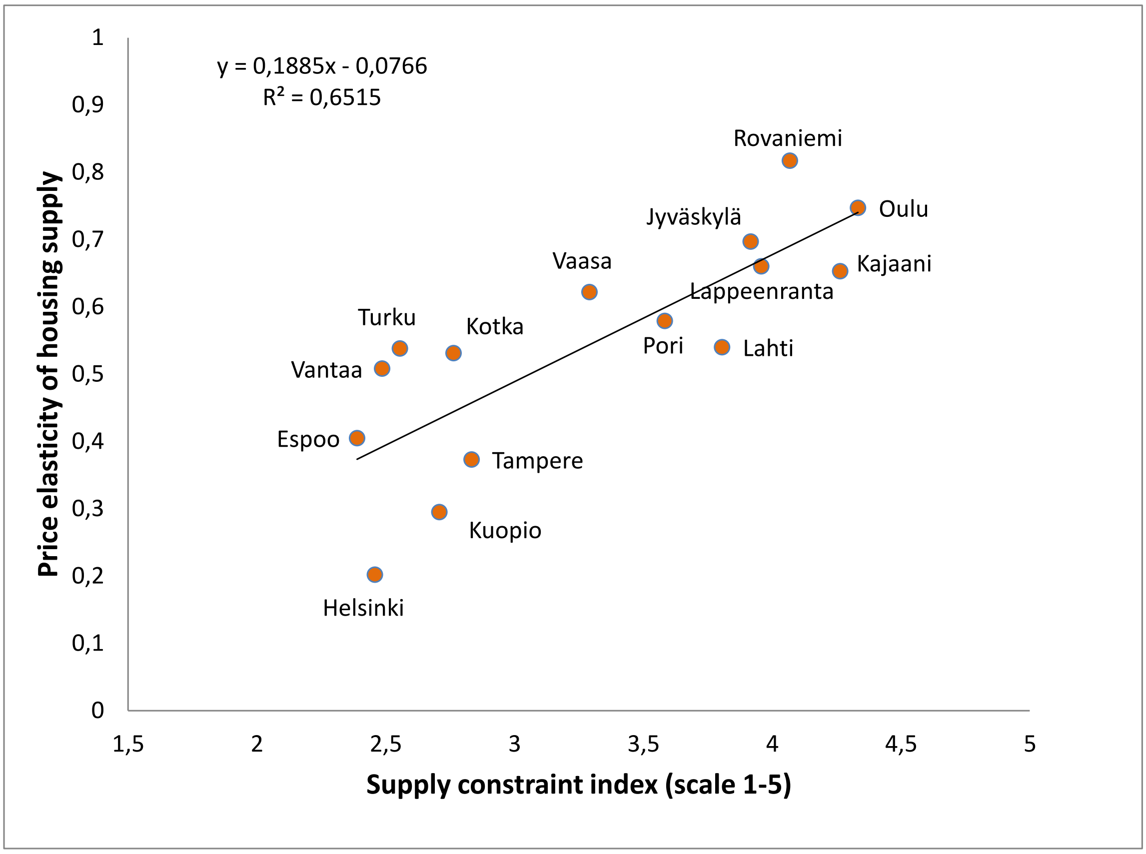


Figure 2 Supply constraint index and the supply elasticity



To study the determinants of supply elasticity variation across regions more carefully, Table 4 reports several model specifications aiming to explain the observed differences. The dependent variable in the estimations is the natural log of supply elasticity. Clearly, the specification in column (1) is problematic. The model includes six explanatory variables while there are only 15 observations. Moreover, simultaneity is almost certainly an issue regarding housing prices (Green et al., 2005), and the numerous explanatory variables exhibit considerable multicollinearity. Hence, it is not unexpected that most parameters are insignificant, and some coefficient signs (growth, density, price) are in contrast with the theoretical predictions and with the pairwise correlation statistics. Nevertheless, this specification is shown in the table, because it corresponds to the theoretical model described in section two on the variables determining the supply elasticity. Similarly, the empirical estimations of Green et al. (2005), which suffer from corresponding complications, yield a number of coefficients signs that contradict with the theory.

The specification in column (2) shows that, together, the city size (population) and the supply constraint index explain almost 70% of the regional elasticity variation. Moreover, both these explanatory variables are highly significant despite the small number of degrees of freedom. This emphasizes the notable role of these variables in the determination of the supply elasticity. The finding also is in line with empirical evidence regarding the U.S. (Saiz, 2010).

The division of our index into its three sub-indices helps explain the variation even better (in terms of the adjusted R^2), columns (3)-(4). It appears that the zoning policies and geographic constraints are the components of the constraint index that affect the elasticity significantly. The more effective role of zoning than of other land policy is consistent with the general view that zoning is the most important land policy tool in Finland. The coefficient on land policy is not statistically significant even if the zoning index is excluded from the model. The coefficients on population, zoning, and geographic constraints are all statistically significant and have the expected sign, and explain together 80% of the observed regional elasticity differences. Importantly, the coefficient magnitudes are of economic significance, too.

Table 4 Cross-section estimations for the supply elasticity

	(1)	(2)	(3)	(4)	(5)	(6)
Explanatory variable	*Coefficient estimate (s.d.)*	*Coefficient estimate (s.d.)*	*Coefficient estimate (s.d.)*	*Coefficient estimate (s.d.)*	*Coefficient estimate (s.d.)*	*Coefficient estimate (s.d.)*
Constant	6.22* (3.03)					
Overall contraint index	.182 (.103)	.301*** (.067)				
Subindex: zoning			.196* (.095)	.179* (.095)	.171* (.086)	.280** (.095)
Subindex: land policy			–.096 (.085)			
Subindex: geography			.175*** (.051)	.139*** (.040)	.109** (.039)	
Log population	–.196 (.168)	–.143*** (.019)	–.128*** (.026)	–.144*** (.023)	–.126*** (.022)	–.122*** (.028)
Pop. growth	21.4* (10.9)					
Log pop. density	.043 (.053)					
Log housing price	–.805 (.574)					
Water bodies ^ 2					–1.11* (.571)	–1.73** (.655)
Model diagnostics						
R-squared	.808	.675	.789	.765	.825	.703
Adj. R-squared	.701	.650	.732	.725	.777	.653
Jarque-Bera (p-value)	.593	.747	.725	.761	.580	.863

*, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively. Jarque-Bera stands for the Jarque-Bera test for normal distribution of residuals. The inclusion of a deterministic constant is decided based on its statistical significance. Log refers to the use of natural log of a variable.

Finally, we investigate whether the share of water bodies brings additional significant explanatory information in the model, which it does. The data reveal that the relationship between supply elasticity and water bodies is non-linear: the best explanatory power is achieved by including the squared share of water bodies in the model, column (5). This specification explains over 80% of the elasticity variation, and even the coefficient of determination that is adjusted for degrees of freedom is close to 80%. The significance of the *squared* water share indicates that the stricter the geographic constraints are, the greater impact additional geographic restrictions (due to water bodies) have on the supply elasticity. Note also that the inclusion of water share does not notably alter the coefficients on the other variables, and the index for geographic constraints remains statistically significant. That is, the two variables capturing geographic constraints contain complementary information that is relevant for the determination of the elasticity. As the geographic constraint index may contain subjective elements due to being based on interviews, we further report specification (6) with water restrictions as the only geographic variable. While the fit of this model is smaller than that of specification (5), the coefficients on zoning and water bodies are greater.

The parameter on population is robust w.r.t. model specification, in models (2)-(6). The best fitting specification (5) indicates that, on average, doubling of city population lowers the supply elasticity by approximately 13%. This creates an additional counter-force for regional concentration of population and jobs. Although less stringent zoning policies do have a significant impact on the elasticity, the opportunities of city administration to increase the elasticity are limited: these possibilities are restricted by the influence of geographic constraints and city size. Note also that the city size and regulation generally 'work' in the same direction. As regulation tends to be more restrictive in the larger cities, there are two forces that decrease the supply elasticity in the bigger cities relative to their smaller counterparts.

Using an interaction variable, we also tested whether, in the similar manner to the findings of Saiz (2010) concerning the U.S., the geographic constraints matter more in larger metropolitan areas. We do not find evidence of such an effect in Finland (this applies to an interaction variable between population and overall regulation index as well). As for robustness of the results in Table 4, the inclusion of Turku, whose elasticity value is estimated indirectly, has only a negligible impact on the results. Similarly, the results do not notably change if the outlier Helsinki (see Figure 1) is excluded from the analysis.

Overall, the results indicate that even in a sparsely populated country with small cities and abundant reserve of developable land in close proximity to the cities, the price elasticity of supply of housing is significantly dependent on city size and geographic constraints, just like the theory suggests. The possibilities to increase the elasticity by more flexible regulation are quite limited – at least within the range of regulatory constraints present in Finland. For instance, in the Helsinki case a change in zoning regulation that would correspond to an increase in the zoning sub-index value from 2.4 to 5 would raise the supply elasticity from 0.20 to 0.29 [specification (5)], which would still be the lowest elasticity within the sample cities. Even the larger coefficient estimate in model (6) would only indicate a rise to 0.35. Hence, the claim that the inelastic housing supply in Helsinki compared with that in the other Finnish cities is mostly due to regulatory constraints does not hold true.

7 Conclusions

The long-term price elasticity of supply of housing is a key factor determining the growth rates of housing prices and housing supply as the city grows. Therefore, the housing supply elasticity has considerable influences on the competitiveness of the region and on the growth potentials of the area. In line with the theory, previous empirical research provides evidence of substantial regional variation in the elasticity, and greater city population, higher population density, and regulatory and geographic constraints significantly decreasing the elasticity as well as explaining a notable part of the elasticity differences across regions. However, many commentators, including some economists, often argue that the theoretical considerations and empirical findings do not apply to a country with very low population density and an abundant reserve of vacant developable land – in these circumstances any notable elasticity differences across regions are likely to be an outcome of variations in local regulatory constraints only, it is claimed.

We examine whether the indications of urban economic theory and previous empirical findings apply to a sparsely populated country with small cities, abundant reserve of undeveloped but developable land, and geographically and culturally coherent regions. Our findings are largely in line with the theory and previously reported empirical results (mainly for the U.S.). Based on quarterly data for the period 1987-2011, the results indicate substantial regional variation in the long-term supply elasticity across Finland, one of the most sparsely populated developed countries. The city size, zoning policies, and geographic constraints are found to be the most significant factors causing the regional elasticity differences across 15 Finnish cities. Together, these factors account for some 80% of the elasticity variations.

We find it remarkable that despite the small number of cross-sectional observations and crudeness of our index of regulatory and geographic constraints, the analysis shows statistically significant effects from the city size, zoning policies, and geographic constraints on the supply elasticity. The estimated coefficients are of economic significance as well, and give support to the theoretical models on housing supply elasticity determination. While more flexible regulation can increase the supply elasticity – and a general policy recommendation is therefore that regional administrations should strive to decrease the regulatory constraints on housing supply to increase the growth potentials of the area – the results imply that the opportunities of regulatory policies to affect the elasticity are limited even in a sparsely populated country or state with small cities and abundant reserve of vacant developable land. Our analysis also includes a methodological contribution: Apparently, no study before ours has used housing stock as the supply variable – likely due to lack of sufficient data and to model stationarity issues – and the Johansen Maximum Likelihood methodology to estimate housing supply elasticities.

In theory, the ongoing concentration of people and jobs to the biggest centers in Finland, due to which greater and greater share of the housing stock is located in the relatively low supply elasticity areas and because of which the elasticity is prone to become even lower, does not necessarily lead to more cyclical housing prices. While on one hand the lower supply elasticity yields more sensitive housing prices w.r.t. economic fundamentals, on the other hand greater cities with broader and more diversified economic bases are likely to have smaller idiosyncratic demand shocks than smaller urban areas. Nevertheless, empirical evidence from the U.S. suggests that housing price cycles are most prominent in the low supply elasticity areas. Similarly, there is a strong negative correlation (−.63) between the city level standard deviation of annual housing price growth and the supply elasticity of housing in Finland. Hence, the growth of the largest urban areas at the expense of the smaller towns is likely to fortify housing price cycles in the Finnish market.

References

Abraham, J. M. and Hendershott, P. H. (1996). Bubbles in metropolitan housing markets. *Journal of Housing Research*, 7(2), 191-207.

Ball, M., Meen, G. and Nygaard, C. (2010). Housing supply price elasticities revisited: Evidence from international, national, local and company data. *Journal of Housing Economics*, 19(4), 255-268.

Blackley, D. (1999). The long-run elasticity of new housing supply in the United States: Empirical evidence for 1950 to 1994. *Journal of Real Estate Finance and Economics,* 18(1), 25-42.

Buckley, R. M. and Mathema, A. S. (2008). Real estate regulations in Accra: Some macroeconomic consequences? *Urban Studies*, 45(11), 2249-2271.

Caldera, A. and Johansson, Å. (2013). The price responsiveness of housing supply in OECD countries. *Journal of Housing Economics*, 22(3), 231-249.

Capozza, D. R. and Helsley, R. W. (1989). The fundamentals of land prices and urban growth. *Journal of Urban Economics*, 26(3), 295-306.

Cheshire, P. and Sheppard, S. (2004). Land markets and land market regulation: Progress towards understanding. *Regional Science and Urban Economics,* 34(6), 619-637.

Dipasquale, D. (1999). Why don't we know more about housing supply? *Journal of Real Estate Finance and Economics,* 18(1), 9-23.

DiPasquale, D. and Wheaton, W. C. (1992) The markets for real estate Assets and Space: A Conceptual Framework. *Real Estate Economics*, 20(2), 181-198.

Doornik, J. A. (1998). Approximations to the asymptotic distributions of cointegration tests. *Journal of Economic Surveys,* 12(5), 573-593.

Eriksen, M. D. and Rosenthal, S. S. (2010). Crowd out effects of place-based subsidized rental housing: New evidence from the LIHTC program. *Journal of Public Economics*, 94(11–12), 953-966.

Glaeser, E. L., Gyourko, J. and Saiz, A. (2008). Housing supply and housing bubbles. *Journal of Urban Economics*, 64(2), 198-217.

Glaeser, E. L., Gyourko, J. and Saks, R. E. (2006). Urban growth and housing supply. *Journal of Economic Geography,* 6(1), 71-89.

Goodman, A. C. and Thibodeau, T. G. (2008). Where are the speculative bubbles in US housing markets? *Journal of Housing Economics*, 17(2), 117-137.

Green, R. K., Malpezzi, S. and Mayo, S. K. (2005). Metropolitan-specific estimates of the price elasticity of supply of housing, and their sources. *American Economic Review,* 95(2), 334-339.

Gyourko, J., Mayer, C. and Sinai, T. (2013). Superstar cities. *American Economic Journal,* 5(4), 167-199.

Gyourko, J. (2009). Housing supply. *Annual Review of Economics,* 1, 295-318.

Gyourko, J. and Saiz, A. (2006). Construction costs and the supply of housing structure. *Journal of Regional Science,* 46(4), 661-680.

Gyourko, J., Saiz, A. and Summers, A. (2008). A new measure of the local regulatory environment for housing markets: The Wharton residential land use regulatory index. *Urban Studies,* 45(3), 693-729.

Harter-Dreiman, M. (2004). Drawing inferences about housing supply elasticity from house price responses to income shocks. *Journal of Urban Economics,* 55(2), 316-337.

Hilber, C. A. L. and Robert-Nicoud, F. (2013). On the origins of land use regulations: Theory and evidence from US metro areas. *Journal of Urban Economics*, 75, 29-43.

Johansen, S. (1996). *Likelihood-Based Inference in Cointegrated Vector Auto-Regressive Models*. Oxford University Press: Oxford.

Johansen, S. (2000). A Bartlett correction factor for tests on the cointegrating relations. *Econometric Theory,* 16(5), 740-778.

Johansen, S. (2002). A small sample correction for the test of cointegrating rank in the Vector Autoregressive Model. *Econometrica,* 70(5), 1929-1961.

Juselius, K. (2006). *The Cointegrated VAR model: Methodology and Applications*. Oxford University Press: Oxford.
Kim, K.-H., Phang, S.-Y. and Wachter, S. (2012). Supply elasticity of housing, in Susan J. Smith et al. (eds.) *International Encyclopedia of Housing and Home*. Vol. 7, Elsevier: Oxford, 66-74.

Koster, H. R. A., van Ommeren, J. and Rietveld, P. (2012). Bombs, boundaries and buildings: A regression-discontinuity approach to measure costs of housing supply restrictions. *Regional Science and Urban Economics,* 42(4), 631-641.

Malpezzi, S. (1999). A simple error correction model of house prices. *Journal of Housing Economics,* 8(1), 27-62.

Malpezzi, S., Chun, G. H. and Green, R. K. (1998). New place-to-place housing price indexes for U.S. metropolitan areas, and their determinants. *Real Estate Economics,* 26(2), 235-274.

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(3), 278-306.

Malpezzi, S. and Mayo, S. K. (1997). Getting housing incentives right: A case study of the effects of regulation, taxes, and subsidies on housing supply in Malaysia. *Land Economics*, 73(3), 372-391.
Malpezzi, S. and Wachter, S. (2005) The role of speculation in real estate cycles. *Journal of Real Estate Research*, 13, 141-164.

Mayer, C. J., and Somerville, C. T. (2000a). Residential construction: Using the urban growth model to estimate housing supply. *Journal of Urban Economics,* 48(1), 85-109.

Mayer, C. J. and Somerville, C. T. (2000). Land use regulation and new construction. *Regional Science and Urban Economics,* 30(6), 639-662.

Mayo, S. and Sheppard, S. (1996). Housing supply under rapid economic growth and varying regulatory stringency: An international comparison. *Journal of Housing Economics,* 5(3), 274-289.

Meen, G. (2005). On the economics of the Barker Review of housing supply. *Housing Studies,* 20(6), 949-971.

Meen, G. and Nygaard, C. (2011). Local housing supply and the impact of history and geography. *Urban Studies,* 48(14), 3107-3124.

Menezes, F. and Pitchford, R. (2004). The land assembly problem revisited. *Regional Science and Urban Economics,* 34(2), 155-162.

Paciorek, A. (2013). Supply constraints and housing market dynamics. *Journal of Urban Economics,* 77(1), 11-26.

Poterba, J. M. (1984). Tax subsidies to owner-occupied housing: An asset-market approach. *Quarterly Journal of Economics,* 99(4), 729-752.

Quigley, J. M. and Raphael, S. (2005). Regulation and the high cost of housing in California. *American Economic Review,* 95(2), 323-328.

Quigley, J. M. and Rosenthal, L. A. (2005) The effects of land use regulation on the price of housing: What do we know? What can we learn? *Cityscape*, 8(1), 69-137.

Rose, L. A. (1989). Urban land supply: Natural and contrived restrictions. *Journal of Urban Economics*, 25(3), 325-345.

Saiz, A. (2010). The geographic determinants of housing supply. *Quarterly Journal of Economics*, 125(3), 1253-1296.

Saks, R. E. (2008). Job creation and housing construction: Constraints on metropolitan area employment growth. *Journal of Urban Economics*, 64(1), 178-195.

Wang, S., Chan, S. H. and Xu, B. (2012). The estimation and determinants of the price elasticity of housing supply: Evidence from China. *Journal of Real Estate Research*, 34(3), 311-344.

Zabel, J. E. (2012). Migration, housing market, and labor market responses to employment shocks. *Journal of Urban Economics*, 72(2–3), 267-284.

APPENDIX A: Supply elasticity estimations for Turku

Table A.1 The estimation of supply elasticity for Turku

Long-run relation for housing supply (k=3) Variables: supply (*s*), income (*y*), credit (*cr*), interest rate (*ir*), construction costs (*cc*)			
Hypothesis	r=0	r≤1	r≤2
Trace test p-values	.06	.27	.26
P-value in the LR test for exclusion of *ir* and *cr*, and weak exogeneity of *cc*, *y*, *cr* and *ir*	.14		
Long-run relation (standard error):	$s = .548y - .707cc$ (.032) (.112)		
Long-run relation for housing price (k=4) Variables: price (*p*), income (*y*), interest rate (*ir*)			
Hypothesis	r=0	r≤1	r≤2
Trace test p-values	.03	.16	.42
P-value in the LR test for exclusion of *ir*, and weak exogeneity of *y* and *ir*	.13		
Long-run relation (standard error):	$p = 1.019y$ (.259)		
Estimate for the long-run price elasticity of housing supply: $e = .548/1.019 = .538$			

Sample period is 1987Q1-2011Q4. Income refers to the aggregate income in Turku. Credit is defined as the total Finnish housing loan stock divided by the Finnish GDP. The credit variable works as a proxy for credit constraints and is needed in the supply model in order to find a stationary relation among the variables. Similarly, a cointegrating relation between price and income can be found only if the real after-tax mortgage interest rate is included in the price model. k is the number of lags in differences included in the estimated models.

APPENDIX B: Survey questions for the regulatory and geographic constraint indices

Zoning:

1. Which actors participate and create pressure in your zoning operations? To what extent? Is there opposition towards the growth of the municipality from politicians or inhabitants within the municipality? If there is any, how does it show up? (The pressure created by state organisations not taken into account, because it is handled in its own separate question.)

2. How much does the Ministry of the Environment, regional Centre for Economic Development, Transport and the Environment or other section of national government participate in your zoning operations? How intense is the control of your region's regional council towards your zoning operations, e.g. compared to the other municipalities within your region?

3. How does the cooperation/lack of cooperation between you and the neighbouring municipalities promote/weaken your ability to plan residential areas?

4. How much does the economic situation of your municipality complicate the zoning an implementation of the residential areas?

5. How much does the protection of environment/buildings/views hinder the zoning of residential areas?

6. What is your usual decision-making process when making new local detailed plans and when making changes to existing local detailed plans? Are there any exceptions in the process? How significantly the appeals challenging the approved plans slow down and hinder the zoning of residential areas in your municipality? How long does it take, on average, from the arrival of a planning initiative to the approval of the plan.

7. Which specific requirements exceeding the minimal statutory requirements are imposed on a building site within your municipality? Do you impose any specific requirements exceeding the minimal statutory requirements for the new residential areas? Do you require the mixing of non-subsidized and publicly subsidised residential construction within the new residential areas?

8. How long does it take, in average, to change the plot division after a plan attains legal force? How long does it take, in average, to subdivide a plot? What is the usual decision making process concerning a building permit, and how long does it take on average to decide on a building permit for a single-family house, a multi-family house or a block of flats?

Tools of land policy:

9. How high proportion of the residential plots is planned on the land owned by the municipality compared to the land owned by other landowners?

10. How eagerly are 'reminders to build' imposed when controlling the implementation of the local detailed plan within your municipality? If the reminder to build is not followed, are the plots then expropriated?

    11. Do you have any targets regarding the zoning of residential construction or building permits for residential construction?

If yes, what kind(s) of targets? Do you even have an official and public definition of zoning and land policy accepted by elected politicians? How have you generally achieved the targets?

Geographic restrictions

12. Are there any specific geographic (or other similar) factors complicating residential construction within the municipality?