Housing Supply Elasticities within the Lower Mainland from 1998 to 2012:

Why is the Vancouver Area so Expensive?¹

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Abstract

Housing affordability in Vancouver is commonly cited as one of the most important issues for the city. The Mayor’s recently established Task Force on Affordable Housing has offered policy solutions such as forcing developers to sell condos 20% below market prices, mandating rental only dwellings, and increasing height restrictions from 3.5 to 6 stories\(^2\). The policy debate on housing affordability ignores substantial academic research which shows that long-run housing prices are determined by the elasticity of the housing supply. This paper estimates housing supply elasticities (HSEs) for twelve municipalities in the Lower Mainland (LM) over the time period of 1998 to 2012. Comparing HSEs between cities tests the hypothesis that the Vancouver area is universally unaffordable. Heterogeneous HSEs suggest that housing unaffordability is policy induced from municipal-specific land-use regulations. The results of this paper are twofold. First, there is an unambiguously negative relationship between long-run housing prices and HSEs. Second, there is substantial heterogeneity in price growth between municipalities. These two results suggest that municipal-specific land-use regulations are driving a large amount of the price growth seen in certain municipalities within the LM.

1 – Introduction

Each municipality in the Lower Mainland (LM) has significant controls over local land-use planning. This devolution of zoning authority provides a natural experiment in terms of measuring the average housing supply elasticity (HSE) of each municipality. The goal of this paper is to estimate HSE differences between LM municipalities and see if they correspond to differences in long-run price growth. The hypothesis of this paper is that cities that have more restrictive building policies\(^3\) will have

\(^2\) See (City of Vancouver 2013).

\(^3\) Many suburbs in Vancouver have seen local residency groups able to influence the type of housing development. Consider that the areas surrounding almost every SkyTrain station from Columbia to Joyce are flanked by high-rises. However, west of 29\(^{th}\) Station to Commercial there are none. These areas have not been allowed to rezone to allow the construction of taller buildings.
lower HSEs, lower population growth, and higher price growth when compared with cities that have high HSEs.

The implication of this hypothesis is twofold. First, housing affordability is dependent on whether municipalities impose restrictive land-use regulations. Second, the commonly cited issue of housing affordability in Vancouver may not be for all of ‘Vancouver’ per se, but rather certain geographic areas within the LM. The word Vancouver has become a synecdoche for the LM in general. This paper will from now on use the word Vancouver when referring to the actual city of Vancouver, and the LM when referring to the collection of the twelve cities being analyzed in this paper\(^4\).

To date there has been neither a measure of an average HSE for the LM as a whole nor for the municipalities within it\(^5\). The most commonly cited measure of housing affordability, the ratio of median house prices to median incomes, is provided as evidence for the LM being one of the least affordable areas in the world\(^6\). However, this measure does not provide an explanation as to why the LM has such a high ratio. A heterogeneous range of HSEs between cities does not necessarily indicate that restrictive land-use regulations are causing these differences. This paper will argue that since most of the parameters that determine HSEs are identical for the municipalities within the LM\(^7\), the only remaining explanation for heterogeneous observations must be due to local land-use regulations.

Supply elasticity is a measure of how responsive output supplied is to a change in price. As seen in equation (1), the number associated with a given HSE implies that a 1% increase in price will cause an ‘\(X\)’% increase in the housing supplied.

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\(^4\) The twelve cities are: Burnaby, Coquitlam, Delta, Maple Ridge, New Westminster, North Vancouver, Port Coquitlam, Port Moody, Richmond, Surrey, Vancouver, and West Vancouver. See Figure 14 for a map of the LM.

\(^5\) The only measured HSE is for Canada as a whole with a measure close to 1.2. See (Bank of Canada 2011).

\(^6\) As of 2013 ‘Vancouver’ was ranked as the second least affordable city in the world by the annual Demographia International Housing Affordability Survey.

\(^7\) Such as building materials, labour costs, taxes, etc.
\[ \varepsilon_{P,H_s(P)} = \frac{\partial H^s(P)}{H^s(P)} / \frac{\partial P}{P} = \frac{\% \Delta H^s}{\% \Delta P} \]  

The prices seen in any housing market are determined by the forces of supply and demand. These forces can be structured as equations, which are likely to be shared for the housing markets in each LM municipality. Consider the variables which make up the housing supply curve: labour costs, input costs, the cost of borrowing, and so on. There is a reasonable expectation that the price of a construction worker or a ton of steel is identical in magnitude for a home being built in either Port Moody or Richmond. After accounting for demand factors, there are three factors that can be expected to differ between municipalities: the median prices of homes, the quantity of housing supplied, and the regulations these cities impose. Prices and housing supplied are measurable, whereas local land-use regulation is not. This implies that any measured differences in HSEs must be determined by the third and immeasurable factor.

The rest of this paper proceeds as follows. Section 2 provides an overview of the related literature and other studies done on HSEs. Section 3 provides an overview of the methodology, including the structural form and the econometric techniques. Section 4 provides an overview of the data sources. Section 5 presents the results, interpretations, and limitations of this study. Finally, Section 6 concludes with final remarks, observations and implications.

2 – Literature Review (Historical and Current)

The classical theories of urban economics were formulated with Alonso Muth’s pioneering *Location and Land Use* in 1964. Muth created a model whereby land prices were explained by bid-rent schedules.

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8 This includes factors like population, amenities, and income earning potential.
9 There have been attempts to quantify the magnitude of regulation for home construction within the United States. See (Gyourko et al 2007) for details. However, a creation of this measure for the LM is well beyond the scope of this paper.
mapped from demand curves which were functions of distance from an urban core. This came to be known as the Monocentric City Model (MCM) and is the basis of most modern theories of housing demand. The theoretical and empirical study of the structural form of housing demand is immense and has received a significant amount of urban economics’ intellectual energy\textsuperscript{10}. Before the 2000s, there was a dearth of research that looked at either theoretical or empirical studies of the housing supply\textsuperscript{11}.

While academic research is a collective endeavor, Edward Glaeser has probably done more than any other academic economist to establish a consensus that the forces which affect the housing supply ultimately determine long-run housing prices\textsuperscript{12}. Glaeser went further in showing how government land-use regulations are fundamental in determining which cities are expensive and which are affordable\textsuperscript{13}. While Glaeser demonstrated that it was ultimately the supply-side that determined long-run prices, not all researchers agreed that restrictive land-use regulation was to blame. Alternate factors that have been cited include natural impediments to growth like mountains or bodies of water\textsuperscript{14}, the political sentiments of local voters\textsuperscript{15}, and taxation policy\textsuperscript{16}. These alternate factors should apply equally when comparing municipalities within the LM. The municipalities within the LM have similar taxation policies, similar natural impediments to growth, and similar political sentiments.

The last decade has also seen a surge of empirical estimates for HSEs. The original MCM assumed that HSEs were completely elastic. In fact, the first two pioneering papers that attempted to measure HSEs were unable to reject the null hypothesis that within the United States HSEs were

\textsuperscript{10} (McDonald 1997) provides a good overview of the classical theories.

\textsuperscript{11} In 1999 (Dipasquale 1999) and (Rosenthal 1999) asked why there was both a lack of theoretical research or quality empirical data on the subject.

\textsuperscript{12} See (Glaeser & Tobio 2007), (Glaeser, Gyourko, and Saks 2006), (Glaeser, Gyourko and Saks 2005), and (Glaeser and Gyourko 2002).

\textsuperscript{13} See (Glaeser & Tobio 2007).

\textsuperscript{14} See (Kolko 2008).

\textsuperscript{15} See (Kahn 2008).

\textsuperscript{16} See (Davidoff 2008).
completely elastic\textsuperscript{17}. There are many empirical estimates of HSEs for cities within the United States\textsuperscript{18}, with some international research conducted as well\textsuperscript{19}. As was mentioned before, no study has looked at individual Canadian cities. The literature lacks consensus on two major issues: the definition of the housing supply, and how to estimate it\textsuperscript{20}. This paper will define the housing supply as the total housing stock. The estimation of each city’s HSE will be based on a Simultaneous Equation Model (SEM) and will identify the supply equation coefficients using the Two-Stage Least Squares (2SLS) estimation technique.

3 – Methodology

The Structural Form

The appeal of measuring HSEs is that their values can be unambiguously compared between cities. A city with a higher measured HSE provide more housing services for the same increase in price compared to another city with a lower HSE. HSEs have a normative interpretation too: they measure how affordable a city is. A city with a perfectly elastic housing supply will have the same long-run price regardless of the magnitude of the demand for housing, because the supply of housing would expand until any short-run price increases will have dissipated. The LM does not have a perfectly elastic housing supply. Even adjusted for inflation, the LM has seen average inflation-adjusted prices double since 1998 as Figure 1 demonstrates. The housing supply curve within the LM must be upward sloping, even in the long-run\textsuperscript{21}.

In order to estimate a SEM with 2SLS, the structure of the supply and demand curves must be chosen. The existing literature provides a framework for potential variables found in supply and demand equations. Tables 1 and 2 provide a cross-literature comparison. Each variable has its own intuitive

\begin{itemize}
  \item \textsuperscript{17} See (Muth 1960) and (Follain 1979).
  \item \textsuperscript{18} See (Blackley 1999) and (Green et al 2005).
  \item \textsuperscript{19} See (Gitelman & Otto 2012) and (Wang et al 2012).
  \item \textsuperscript{20} (Kim et al 2010) provides an excellent overview of different studies and their techniques.
  \item \textsuperscript{21} Defining how long the long-run takes is a matter of debate, but fifteen years seems a sufficient time period.
\end{itemize}
appeal. Two sorts of demand equations exist: one which measures only new housing construction and one which measures the overall housing stock. Housing is a durable good which means the availability of housing services, which is ultimately what matters to housing demand, is determined by both new supply and preexisting stock. Many models use new housing construction as a proxy for long-run housing services. In the long-run, if the housing stock and population continuously expands then it would not matter if the dependent variable was either new home construction or the total housing stock. This paper will use the total housing stock to measure HSEs. The total housing stock seems the most relevant measure of total housing services over a fifteen year period.

Equation (2) shows a demand equation with all the variables used throughout the literature. ‘Q’ is a measure of housing supply, ‘P’ is the housing price, ‘Y’ is income, ‘M’ is population, the lagged ‘K’ is the housing stock in the previous period, ‘r’ is either the real or nominal interest rate, ‘PO’ is the price of relative goods, ‘OWN’ is the ownership rate, and ‘R’ is the rental price of housing. Equation (2) is unrealistic as the use of all known variables would cause unnecessary multicollinearity as well as introduce theoretical issues. Furthermore, no model in the literature has ever included all of these variables at the same time.

\[
Q_t^D = a_0 + a_1 P_t + a_2 Y_t + a_3 M_t - a_4 K_{t-1} + a_5 r_t + a_6 P_O + a_7 O_W N_t + a_8 R_t \tag{2}
\]

The three variables which have the least intellectual appeal to this study are the prices of relative goods, the ownership rate, and the rental price of housing. The price of relative goods will have little effect on housing demand, due to the necessity of shelter, which creates an inelastic demand. The ownership rate is unlikely to be an explanatory variable. Instead, the ownership rate is caused by the structure of supply and demand rather than an exogenous variable influencing it. Additionally, the ownership rate would introduce unnecessary multicollinearity due to its negative linear relationship with housing prices.
Rental homes are a substitute for owner occupied homes, but as the LM has rent controls, the prices observed in the market will be distorted by this policy. Equation (3) shows the structure of the demand equation that will be used for this paper. Housing demand is a function of prices, income, population, a fixed effect, and a stochastic demand shock term ‘z’.

\[ Q_t^D = \alpha_0 + \alpha_1 P_t + \alpha_2 Y_t + \alpha_3 M_t + b + z_t^D (3) \]

Equation (4) shows a supply equation with all the variables used throughout the literature. ‘CX’ is the price of construction materials and ‘LX’ is the price of labour.

\[ Q_s = \beta_0 + \beta_1 P_t + \beta_2 P_{t-1} + \beta_3 P_{t-2} + \beta_4 CX_t + \beta_5 LX_t + \beta_6 r_t (4) \]

Using past-period prices implies static expectations about future prices. This learning mechanism has limited appeal in the LM real estate market which has an upward price trajectory. The cost of capital is an incredibly important variable for developers but has the weakness that it is correlated to the price of housing. Housing prices are a function of the real interest rate, and including it in the model will introduce multicollinearity and weaken the results. Due to its importance, two supply equations were ultimately used: one with and one without a real interest rate variable. The final issue with equation (4) is that in the long-run the structural housing supply equation will be a function of either the price, or the average costs, but not both\(^{22}\). In a market with free entry and limited start-up costs\(^{23}\), the long-run supply curve will converge to the average cost curve which will drive the market price to average costs as well. From a measurement perspective it is much easier to acquire data on market prices than a vector of input costs associated with construction; some of which are incredibly difficult to observe like regulatory costs and legal fees. The supply equation specification in this paper takes the simple form of

\(^{22}\) This point is well argued in (Malpezzi & Maclennan 2001) and provides the basis for equation (5).
\(^{23}\) This characterizes most of the housing industry. See (Gyourko & Saiz 2006).
equation (5) which defines housing supply as a function of housing prices and a stochastic supply shock term ‘v’.

$$Q_t^s = \beta_0 + \beta_1 P_t + v_t^S \quad (5)$$

An alternative specification, equation (6), is also used due to the importance of the cost of capital. The cost of capital is not fully determined by market forces due to the influence of the Bank of Canada. Capital costs may be the one variable independent of a long-run equilibrium.

$$Q_t^s = \beta_0 + \beta_1 P_t + \beta_2 r_t + v_t^S \quad (6)$$

City-specific vs. LM-specific Variables

The twelve cities being analyzed have twelve sets of supply and demand equations. Determining which variables are city-specific versus LM-specific is important. The three variables which are city-specific are the housing supply, the price of housing, and the city fixed-effect. The two variables which are LM-specific are population and income. The assumption being made is that the market for housing in the LM is system wide. An individual only looks at factors like distance to work, preference for neighborhoods, etc. All of these factors are independent of arbitrary lines that demarcate where a city starts and ends. Put another way, this model assumes that if a person wants to live within 10km of his place of employment he/she does not care if that home is Burnaby or Coquitlam, ceteris paribus\(^24\). This

\(^{24}\) One weakness with this assumption is that because municipalities charge different rates for property taxes and utilities this may influence preference for municipal location. However the fixed-effect variable in the demand equation may be able to capture most of this.
assumption implies that when a person becomes employed and earns a salary, the purchasing power of that salary can be expressed in a demand schedule equally for all LM municipalities.<sup>25</sup>

Equations (7) and (8) show the demand and supply equations with city-specific and LM-specific subscripts. The subscript ‘i’ denotes when the variable is city specific. As equation (7) shows, there is a fixed-effect effect on the demand side. This must be true as an equivalent home in West Vancouver will sell for more than an equivalent home in East Vancouver due to the greater amenities in the former. The fixed-effect will not affect the estimate of beta(1), as each regression is run individually and not as a pooled cross section or panel data.<sup>26</sup> Effectively, the fixed-effect along with alpha(0) will be absorbed into the intercept. The dependent variable of both equations is measured as the cumulative housing stock.

\[
Q^{D}_{i,t} = \alpha_{i0} + \alpha_1 P_{i,t} + \alpha_2 Y_t + \alpha_3 M_t + b_i + z^{D}_{i,t} \tag{7}
\]
\[
Q^{S}_{i,t} = \beta_{i0} + \beta_1 P_{i,t} + \nu^{S}_{i,t} \tag{8}
\]

In order to measure HSEs the coefficient beta(1) must represent a constant elasticity. Equation (8) implies a linear supply curve that has a falling HSE with respect to price. The relationship between housing prices and quantity supplied needs to be nonlinear in order to account for this. The log-log specification implies a constant price elasticity of supply and will be used as the structural form for the supply and demand equations.<sup>27</sup>

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<sup>25</sup> This of course is a simplification as some people have no interest in living in downtown Vancouver because it’s too dense or in West Vancouver because it’s too haughty. To the extent that individuals have a random distribution of preferences for certain municipalities, these effects should cancel out.

<sup>26</sup> Note equation (8) specifies the fixed-effect as a constant but some researchers, see (Gyourko et al 2006), have argued that some cities can have higher price growth, particularly glamour cities. This paper disregards this argument.

<sup>27</sup> Equation (10) will from now on be used to demonstrate the methodology, however using equation (11) yields the same qualitative results.
\[
\log(Q_{it}^D) = A + \alpha^1 \log(P_{it}) + \alpha^2 \log(Y_t) + \alpha^3 \log(M_t) + \log(z_{it}^D) \quad (9)
\]
\[
A = \log(\alpha_{i0}) + \log(b_i)
\]
\[
\log(Q_{it}^S) = \log(\beta_{i0}) + \beta^1 \log(P_{it}) + \log(v_{it}^S) \quad (10)
\]
\[
\log(Q_{it}^s) = \log(\beta_{i0}) + \beta^1 \log(P_{it}) + \beta^2 \log(r_t) + \log(v_{it}^S) \quad (11)
\]
\[
\beta^1 \approx \frac{\%\Delta Q_i^S}{\%\Delta P_i} \quad (12)
\]

The Simultaneous Equation Model

The price and output observed in the market are determined jointly by equations (9) and (10). The supply and demand equations share the same variable, price. An estimate of equation (10) will be biased because the market price observed will be correlated with the stochastic error terms from both the supply and demand equations. This is because a shock to demand will change the observed market price. The market price can be expressed as a reduced form of the exogenous and stochastic parameters of equations (9) and (10) by setting these two equations equal to each other and solving for price.

\[
\log(P_{it}^*) = \gamma_0 + \gamma^1 \log(Y_t) + \gamma^2 \log(M_t) + \epsilon_{pl} \quad (13)
\]
\[
\gamma_0 = \frac{A - \log(B_{i0})}{\beta^1 - \alpha^1}, \quad \gamma^1 = \frac{\alpha^2}{\beta^1 - \alpha^1}, \quad \gamma^2 = \frac{\alpha^3}{\beta^1 - \alpha^1}, \quad \epsilon_{pl} = \frac{\log(z_{it}^D) - \log(v_{it}^S)}{\beta^1 - \alpha^1}
\]

The reduced form of price in equation (13) is a function of the both stochastic error terms ‘z’ and ‘v’. An OLS estimate will be unbiased if the covariance between the price and the error term is zero. This will clearly not be true\(^{28}\).

\(^{28}\) The following equations disregard logs for notational simplicity.
\[
\text{cov}(P_{it}, v_{S_{it}}) = \text{cov}(\gamma_0 + \gamma_1 Y_t + \gamma_2 M_t + \epsilon_{pt}, v_{S_{it}}) \iff \\
\text{cov}\left(\frac{-v_{S_{it}}}{\beta_1 - \alpha_1}, v_{S_{it}}\right) \iff \frac{1}{\beta_1 - \alpha_1} \text{var}(v_{S_{it}}) = \frac{\sigma_v^2}{\beta_1 - \alpha_1} \neq 0
\]

In order to produce an unbiased estimate of \( \beta(1) \) for a SEM model, at least one exclusion restriction (ER) must be identified. An ER is an exogenous variable that is found in the structural demand equation (9) but not the supply equation (10). An exclusion restriction has two important qualities: it is uncorrelated with the error term (exogeneity) and correlated with the endogenous variable (relevance).

Equation (9) has two exclusion restrictions (ERs): income and population. To see how these two ERs can identify the coefficient of price in equation (10), that is to say remove the covariance between price and the error term, consider the reduced form of quantity and price. Inserting equation (13) into equation (10) yields the reduced forms of quantity expressed as a function of exogenous and stochastic variables.

\[
\log(Q_t) = \pi_0 + \pi_1 \log(Y_t) + \pi_2 \log(M_t) + \epsilon_{qt} \quad (14)
\]

\[
\pi_0 = \beta_1 \gamma_0 + \log(B_{i0}), \pi_1 = \beta_1 \gamma_1, \pi_2 = \beta_1 \gamma_2, \epsilon_{qt} = \epsilon_{pt} + \nu_{it}
\]

The reduced form equations of quantity and price are the mechanism for identifying an unbiased \( \beta(1) \). The ratio of coefficients from the exclusion restrictions in equation (13) and (14) are equal to the parameter of interest, the HSE from equation (10). This identification is known as the ratio of reduced forms (RRF).

\[
\frac{\pi_1}{\gamma_1} = \frac{\beta_1 \gamma_1}{\gamma_1} = \beta_1, \frac{\pi_2}{\gamma_2} = \frac{\beta_1 \gamma_2}{\gamma_2} = \beta_1 (15)
\]

The estimates of the coefficients from equations (13) and (14) will be able to provide an estimate of \( \beta(1) \). This is only true asymptotically however. Any one particular estimate will likely yield two different results, due to the stochastic nature of our model.
The RRF method of estimation has no way of determining which ratio of coefficients is the correct one. In this situation, using the 2SLS method is more effective than the RRF method as it can use data from both ERs.

2SLS Estimation Method

The advantage of having more ERs than endogenous variables, an overidentified model, is that both variables can help to identify the endogenous variable’s coefficient. There are two steps to the 2SLS estimation method. The first is to take the OLS of the reduced form of price, equation (13), and use the fitted values as an instrument for price in equation (10).

\[
\log(\widehat{P}_{it}) = \gamma_0 + \gamma_1 \log(Y_t) + \gamma_2 \log(M_t) (17)
\]

The fitted values of the dependent variable, ‘P-hat’, are said to be purged of their endogeneity. These fitted values represent the component of price that is not correlated with the error terms in either the supply or demand equations. If the ERs, income and population, were correlated with the error term, then the fitted values of equation (17) would be endogenous. This is why exogeneity of the ERs is a critical assumption. The second step is to estimate the equation of interest using the fitted values from equation (17) as the instrument for the endogenous variable, price.
Stage 2 – Estimate equation (10) with ‘P-hat’

\[
\log(Q_{i,t}^s) = \log(\beta_{i,0}) + \beta_1 \log(P_{i,t}^s) + \log(v_{i,t}^s) \quad (18)
\]

\[
\hat{\beta}_{1,2SLS}, \min \sum \hat{v}_{i,t}^S
\]

Testing for Relevance and Exogeneity

Determining whether the ERs, income and population, are relevant is straightforward. If the ERs are correlated with the endogenous variable, then the coefficients from the estimate of equation (13) should be statistically significant, nonzero, and have an F-Test score implying joint significance. An advantage of having an overidentified model is that the ERs can be tested for exogeneity. This test is known as the Sargan test and there are two steps to it. The first step is to obtain the residuals from the 2SLS estimation on equation (10). The second step is to regress these residuals on the ERs and keep the R-squared.

\[
\hat{v}_{i,t}^S = \mu_0 + \mu_1 \log(Y_t) + \mu_2 \log(M_t) + \omega_t \quad (19)
\]

Under the null hypothesis that the ERs are exogenous, the R-squared from equation (19) times the number of observations, should be less than the chi-squared distribution, with ‘q’ degrees of freedom, at a ‘X’% significance level. The model in this paper has two ERs, one degree of freedom, 180 observations, and will use a 5% significance level.

\[
H_0: n\hat{R}_v^2 < \chi^2(q) \iff 180 \times \hat{R}_v^2 < 3.841 \quad (20)
\]

\[
H_1: n\hat{R}_v^2 > \chi^2(q) \iff 180 \times \hat{R}_v^2 > 3.841
\]
Correcting for Autocorrelation

Empirical studies have shown price persistence in many US housing markets. Stochastic shocks to both housing supply and demand are likely to be serially correlated. A model has AR(1) serial correlation when the error term is a fraction, ‘rho’, of the previous error term as well as a pure stochastic element, ‘e’.

\[ v_{it}^S = \rho v_{i,t-1}^S + e_{it}^S \]  

(21)

Testing for AR(1) serial correlation can be done in two ways. The first method is to use the lagged residuals obtained from the 2SLS estimate of equation (10), and repeat the 2SLS process with the lagged residuals as an exogenous variable.

\[ \log(Q_{it}^S) = \log(\beta_{i,0}) + \beta_1 \log(P_{it}^S) + \omega(v_{i,t-1}^S) + e_{it}^S \]  

(22)

A statistically significant nonzero estimate of ‘omega’ implies AR(1) serial correlation. The second method is to use the Durbin-Watson test by calculating Durbin-Watson (DW) test statistic, ‘DW’.

\[ DW = \sum \left( \frac{\hat{v}_{i,t}^S - \hat{v}_{i,t-1}^S}{\hat{v}_{i,t}^S} \right)^2 \]  

(23)

---

29 Evidence for this phenomenon has been empirically documented since 1984; see (Gau 1984). For a recent study see (Schindler 2012).

30 For example, a crime wave shock in one municipality is likely to depress prices for more than one period.
The null hypothesis of the Durbin-Watson test is rejected when ‘DW’ is below the lower critical value, not rejected if it is above the upper critical value, and inconclusive if it lies between the lower and upper critical values. The critical values for model this model using a 5% significance level are seen in equation (24).

\[ H_0: DW > d_u \iff DW \geq 1.77 \quad (24) \]
\[ H_1: DW < d_l \iff DW \leq 1.71 \]

This paper will employ the DW test to check for AR(1) serial correlation. If the null hypothesis is rejected, the 2SLS model will produce standard errors, and hence t-scores, that are not valid. The 2SLS standard errors will be smaller than the true standard errors weakening the strength of the results. To purge the model of the putative serial correlation all dependent, explanatory, and endogenous variables, along with the ERs need to be quasi-differenced. Quasi-differencing can be done by subtracting the lagged variable from each variable by the factor of the AR(1) serial correlation, ‘rho’.

\[
\begin{align*}
\overline{Q}_{st}^s &= Q_{st}^s - \rho Q_{s(t-1)}^s, \overline{P}_{st} = P_{st} - \rho P_{s(t-1)} \\
\overline{Y}_t &= Y_t - \rho Y_{t-1}, \overline{M}_t = M_t - \rho M_{t-1}
\end{align*}
\]

An estimate of ‘rho’ is obtained from equation (21). After all the variables have been quasi-differenced, the whole 2SLS process is repeated.

**Determining the Dependent Variable: Housing Supply**

The heterogeneity of housing makes measuring the housing supply a challenge. In theory, the housing supply should be a measure of total housing services. However what can actually be measured are buildings rather than the flow of housing services from these buildings. Measuring only the number
of buildings will understatement the HSEs of dense cities and overstate the HSEs of sprawling cities. There are three solutions for this problem. The first is to accept bias. The second is to measure the HSEs of various types of buildings. Finally, the third is to measure housing stock per person. The first two options will be used in this paper. Even though measuring total buildings imposes bias, the hypothesis of this paper is that dense cities also have the highest overall HSEs. Restrictive building policies are associated with minimum lot sizes, height restrictions, and restrictive covenants that preserve the ‘character’ of neighborhoods. All three policies restrict all types of buildings.

The second solution will be used as a robustness check. The hypothesis of this paper will be confirmed if the municipalities that have high HSEs for all building types also have high apartment supply elasticities (ASEs). The third solution will not be used. Measuring housing stock per person has an endogeneity issue. A higher denominator means a lower HSE, so cities which have the fastest growing populations will suffer from a downward bias. The population of a city is intimately tied to the number of buildings in a city. Measuring HSEs per person gives areas which see low population growth (possibly because of high prices due to restrictive building policies) seem more elastic than they actually are. This measure will not be used.

One of the three hypotheses of this paper is that areas which have a high HSE will see higher population growth. To test the relationship between the HSE and population levels, the dependent variable ‘Q’ will be replaced with the population of that municipality. Doing so will yield a population supply elasticity (PSE). Three dependent variables will be used for equation (10).

31 The flow of housing services from a thirty-story apartment is a multiple of a single-family home, although both are measured as only one structure.
\log(Q_{i,t}^{s}) (26)
\log(APT_{i,t}^{s}) (27)
\log(M_{i,t}) (28)

For each municipality ‘i’, ‘Q’ is a measure of the total housing stock of all building types, ‘APT’ is a measure of the total housing stock of apartment buildings, and ‘M’ is a measure of the population.

4 – Data and Limitations

The timeframe of this study is from January 1998 to December 2012. All data is monthly. The housing price data comes from the British Columbia Real Estate Association’s CREA II database. The database decomposes home sales for city-specific neighborhoods and building type. The prices are the median monthly sale price. Median price data excludes outliers and is more representative of what an ‘affordable’ home is. Median prices used for HSEs are the best measure of long-run housing affordability, which is the metric this paper is seeking to quantify.

Two types of monthly population data are used. The data for the variable ‘M(t)’ in the demand equation (9) comes from the Labour Force Survey (LFS) and is a three-month moving average of individuals older than fifteen in the LM. The total population in the LFS data includes some small municipalities other than the twelve municipalities studied in this paper. The LM population data therefore serves as a proxy for the twelve municipalities. To the extent that population growth is not significantly different in the excluded municipalities, there should be no bias introduced in the estimates. The data for the variable ‘M(i,t)’ in equation (10) is the municipal-specific population and

\[______________32\] Average prices would have a rightward skew and make housing prices seem less affordable than they actually are.

\[______________33\] Statistics Canada defines the metropolitan area Vancouver, code 59933, as more than the twelve municipalities studied in this paper. This area includes cities like Pitt Meadows, White Rock, and so on. For a full list of included municipalities see link in the Data Reference section.
comes from the annual population estimates in the census. To turn the annual data into monthly data, a simple linear estimate added $1/12$ of the yearly change onto each month\textsuperscript{34}. Since yearly population growth averaged around 1-2\% for most municipalities, the estimate of a city’s monthly population growth will not be significantly different from the actual level.

The weekly median wage data for fulltime employees in British Columbia weighted by sector is used as a proxy for the monthly income variable ‘$Y(t)$’. A proxy was necessary as no publically accessible monthly income data exists for the LM. The constructed proxy used the sectors most relevant to the LM such as management, finance, and service occupations. Primary sectors of the economy, like forestry, were not included. To the extent that median wage growth is similar throughout the province in the non-primary sectors, and the composition of these sectors does not significantly differ geographically, then the bias of the proxy will not be significant.

5 –Results, Interpretations, and Limitations

Table 3 provides summary statistics for the different municipalities. Between 2001-2011 municipalities, such as Port Moody, saw a large increase in total housing stock whereas others, such as West Vancouver, saw very little. Port Moody and West Vancouver had the highest and lowest population growth rates respectively. Price growth was significant in most cities but the ratio of price growth to housing stock growth varied between cities. Not surprisingly, Port Moody and West Vancouver had the lowest and highest ratio of price growth to housing stock growth respectively.

Tables 4 and 5 provide an initial estimate of HSEs using a simple OLS for both supply equation specifications. Tables 6 and 7 contrast the results of the simple OLS with the 2SLS method. HSEs are unambiguously higher for both supply equation specifications when the 2SLS method is used. HSEs are

\textsuperscript{34} The twelve month period from the start to the end of 2012 was estimated too.
unambiguously lower for the supply equation specification that includes a real interest rate variable\textsuperscript{35}. All HSE results are statistically significant. Four of the twelve coefficients for the real interest rate are insignificant and one has an unexpected sign using the 2SLS method\textsuperscript{36}. However the unexpected sign is within one standard error of zero. Tables 6 and 7 provide evidence for two sets of HSEs. The real interest rate variable is significant for eight of the twelve municipalities and has the expected sign for eleven of them. This suggests that including the interest rate variable is providing additional information. Both specifications achieve two qualitatively similar outcomes which imply robustness. First, the differences in estimates are small, and second, the relative rankings between municipalities for HSEs are similar.

Tables 8 and 9 present the estimates of the PSEs using the 2SLS method. All results are statistically significant. However, the coefficient for Delta has an unexpected negative sign. Delta had almost no population growth over the 15-year period\textsuperscript{37}, and therefore it is not surprising that its PSE estimate comes close to zero. Estimating PSEs with the 2SLS method does not have the same interpretation that it does for HSEs. The PSE is a metric designed to measure the relationship between population growth and prices. The purpose of its calculation is to demonstrate the link between population growth, HSEs, and price affordability.

Figure 2 provides evidence to confirm the hypothesis that municipalities with high HSEs have high population growth rates. The relationship is close to perfectly linear. This is not surprising because of the intimate link between the housing stock and the population of a city. Figure 3 provides a graphical ranking of cities by HSE and PSE. Figure 4 provides evidence to confirm the hypothesis that municipalities with low HSEs will see the highest housing price growth. There is an unambiguous negative relationship between price growth and HSEs. The correlation coefficient between long-run

\textsuperscript{35} Except for Port Moody.
\textsuperscript{36} Yellow boxes denote statistical insignificance at a 5% significance level.
\textsuperscript{37} The population of Delta grew by only 848 people, less than 1% of its total population, from January 1998 to December 2012.
housing prices and HSEs, excluding Delta, is close to a perfect negative relationship measuring -0.95. The correlation coefficient between long-run housing prices and PSEs is -0.85. The negative correlation between prices and population may seem counterintuitive. However, evidence from this paper shows that the number of houses is the primary driver of prices, and not population.

Tables 10 and 11 show the estimates for apartment supply elasticities (ASEs) using the 2SLS method with both supply equation specifications. All of the ASE results are significant. While three of the twelve coefficients for the real interest rate variable were insignificant, all had the correct sign. The inclusion of the real interest rate variable lowers the ASEs for each municipality as in the case of the HSEs. While some municipalities have a higher HSE compared to their ASE, the correlation coefficient between the two measures is 0.86. Figure 5 provides evidence to confirm the hypothesis that municipalities which have high overall HSEs will also have high elasticities for other building types. The R-squared and correlation coefficient of 0.74 and 0.86, respectively, demonstrate the link between HSEs and ASEs. The potential criticism that dense cities’ HSEs would be systematically underestimated is unlikely to be relevant given the strong linear relationship between the overall housing stock and the number of apartments.

Table 12 presents the estimates for the relevance and exogeneity of the ERs. Relevance is determined by regressing the endogenous variable, price, on the ERs. The coefficients of the wage and population ERs are insignificant in four municipalities. The F-Test provides a method to determine if including both variables provides a better fit to the data than only including one. An F-Statistic above 3.05 implies joint significance for both ERs at a 5% significance level. All municipalities have significant F-Statistics. The result is not surprising as intuition suggests that population and income are part of the structural demand equation. The four cases of insignificance may be explained by multicollinearity.

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38 The historically low interest rates in Canada throughout the period may explain why including the real interest rate variable lowers elasticities.
between population and income. A higher wage rate in the LM will likely cause a higher inward migration.

Table 12 also presents the estimates of the Sargan values which test for instrumental exogeneity. The Sargan test rejects the null hypothesis of instrumental exogeneity for any value above 3.84 at a 5% significance level with one degree of freedom. The results are concerning. The null hypothesis is rejected in nine of the twelve municipalities. The ERs may be failing the test because one of the ERs is exogenous but the other is not. Unfortunately there is no way to test for this because the Sargan test requires overidentification, and removing one of the ERs would leave an exactly identified model. Exogeneity is rejected when the R-squared obtained from regressing the residuals on the ERs is too high. Two potential reasons for a high R-squared include heteroskedasticity and serial correlation of the residuals\(^\text{39}\).

Rows 1 to 4 from Table 13 show evidence for AR(1) serial correlation in the residuals for both supply equation specifications. The DW statistics are below the lower critical value, 1.71, for all municipalities under both specifications for HSEs and ASEs\(^\text{40}\). The null hypothesis of no serial correlation is rejected in every case. Figures 6 and 7 provide an obvious visual demonstration of the serial correlation seen in the residuals obtained from the 2SLS estimates. Serial correlation is the likely explanation as to why the Sargan tests are rejecting exogeneity. The two ERs, income and population, have an upward slope for the whole 15 year period. The residuals trend upwards from around 2003-2008. There is likely enough coincidental covariance between the residuals and the ERs during this time period to make the R-squared high enough to reject exogeneity. There is a strong possibility that the ERs are exogenous, but that the persistent residuals are biasing the results. To see whether the residuals

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\(^{39}\) There is also the possibility that the instruments are just endogenous, which would be unfortunate.  
\(^{40}\) Yellow boxes denote a rejection of the null hypothesis of the DW test.
could be corrected for AR(1) serial correction, the 2SLS was modified to the quasi-differenced approach described in the methodology section.

The results of the quasi-differenced 2SLS estimates are presented in Tables 14 to 17 for both HSEs and ASEs under both specifications. The results are not encouraging. The HSEs differ between the 2SLS method and the 2SLS method with the quasi-differenced approach. The differences are ambiguous as some of the results are higher whereas others are lower for different municipalities. Adjusting for serial correlation is meant to adjust the standard errors and remove serial correlation rather than change the estimates. The real interest rate variable becomes statistically insignificant for the majority of municipalities and the wrong sign appears in many cases. Figures 8 and 9 show that quasi-differencing does lessen some of the trend in serial correlation. Rows 5 to 8 in Table 13 show the DW statistics for the new quasi-differenced estimates. Unfortunately, the majority of estimates still have residuals that are serially correlated\footnote{Purple boxes denote that the DW null hypothesis was not rejected and orange boxes denote that the test was inconclusive.}

Quasi-differencing does not improve the model. Serial correlation is still present and there are strange effects in the estimates of the HSEs and ASEs\footnote{Quasi-differencing causes Vancouver’s HSE to drop to close to zero, and Delta’s ASE to become negative.}. There are many reasons why the data may be insensitive to AR(1) correction techniques. The root of the autocorrelation function may be higher than one, and in fact may be a polynomial.

\[ v_{i,t}^S = \rho^1 v_{i,t-1}^S + \ldots + \rho^n v_{i,t-n}^S + e_{i,t}^S (29) \]

A second possibility may be nonlinear effects which are not being fully captured by the linear model. While autocorrelation with polynomial roots and nonlinear effects can be accounted for, they require sophisticated statistical techniques beyond the scope of this paper.
Limitations

The results of this paper must accept the bias that occurs from the serially correlated residuals. Nevertheless, the effects of serial correlation are not severe enough to cause consternation. First, serial correlation does not bias the estimates. Second, the residuals display a similar pattern across all municipalities. Any distortions in standard errors are likely similar for all municipalities. Serial correlation does create two significant weaknesses in the results. The first is the weakened ability to determine which supply equation specification is more precise. Standard errors are biased downwards from serial correlation. Many municipalities already have insignificant estimates for the real interest rate variable. Without serial correlation, the number of insignificant real interest estimates would probably increase\(^{43}\).

The second and more serious issue is the potentially endogenous ERs. The inability to remove serial correlation removes the ability to prove the exogeneity of the ERs. The 2SLS method requires exogenous ERs. The failure to provide evidence for this assumption remains an outstanding weakness of this paper. Future research may be able to confirm the results of this paper through more sophisticated nonlinear specifications and polynomial autocorrelation correction mechanisms for the residuals. Better monthly data may also improve the results. The wage and population ERs are proxies and their unbiasedness is conditioned on certain assumptions that may not be true.

Underlying Factors

The findings of this paper have incontrovertibly demonstrated that there is an almost perfect negative causal relationship between prices and supply. Demonstrating that supply constraints are policy induced, and hence voluntary, is more of a challenge. Two methods can be used to do so. The first method is providing evidence that other putative explanatory variables are not relevant. Two commonly

\(^{43}\) After quasi-differencing the residuals, the magnitude of serial correlation fell and the number of insignificant real interest rate coefficients increased.
cited reasons for the LM’s high prices are geography and international appeal. Geography may be a factor for the LM as a whole, but not for any one municipality. In fact Port Moody, which has the highest estimated HSE, is the smallest municipality and is geographically constrained by the Coquitlam Watershed, Cypress Mountain, and Burrard Inlet. Furthermore, one geographical constraint that varies by municipality is the amount of land that cannot be developed for any sort of housing because it is part of the Agricultural Land Reserve (ALR).\textsuperscript{44} Intuition would suggest that municipalities which have more land in the ALR as a percent of their land base will have higher prices. Figure 10 demonstrates there is no positive relationship between the amount of land in the ALR and long-run price growth.

Vancouver is known as an international ‘glamour city’. Immigrating to the LM is attractive because of the large pre-existing ethnic populations already established in the region. One suggestion is that cities with large ethnic populations, such as Burnaby and Richmond, will see higher price growth because of a combination of international and domestic demand. Figure 11 demonstrates that there is no relationship between long-run price growth and the percent of the population that speaks a non-official language at home.\textsuperscript{45} Ultimately, long-run price growth is driven by the supply of homes and not demand factors such as international appeal.

The second method is to provide evidence that municipal-specific policy decisions are leading to long-run price growth. This can be done in two steps. The decision to issue building permits is at the complete discretion of any municipality. Figure 12 demonstrates the tight link between the number of permits issued per person and the HSE of that municipality.\textsuperscript{46} Municipalities can significantly influence their HSEs by issuing more permits. Figure 13 shows the negative relationship between per capita

\textsuperscript{44} The amount of land in the ALR is controlled by the Agricultural Land Commission and not individual municipalities.

\textsuperscript{45} There is technically a positive correlation but the R-squared is close enough to zero that there is effectively no relationship.

\textsuperscript{46} Per capita permits are averaged yearly over the 1998-2012 time period. Building permits were for all residential building types: single-family dwellings, apartments, and so on.
building permits and long-run price growth. Municipalities can influence long-run price growth by issuing more or fewer permits.

6 – Conclusions

The findings of this paper are well aligned with similar studies in the United States\(^\text{47}\). Cities that have higher HSEs will have more affordable housing. The techniques and analysis of this paper may be complex but the underlying intuition is simple. Market prices are determined by both supply and demand. A flexible supply is both a necessary and sufficient condition to ensure low prices. The issue of affordable housing has an interesting parallel to the debates over inflation in the 1970s. There was actually only one reason for persistent inflation: the supply of money. Various intuitive explanations such as unions, cost-push, demand-pull, and oil shocks were put forward to explain inflation. All of these explanations had a kernel of truth but were fundamentally misleading.

The housing affordability debate in the Lower Mainland is marked by a new set of intuitive, albeit misleading, explanations. Factors such as property speculation, geography, immigration, low interest rates, and the Agricultural Land Reserve are all put forward to explain high prices. Heterogeneous measurements of long-run price growth occur between municipalities even after considering these factors. A crisis of affordable housing is not occurring in every municipality. The LM is not, as a whole, unaffordable, but rather certain municipalities within it are unaffordable.

A public discussion about housing affordability, without a discussion about increasing the housing supply, is not meaningful one. The results of this paper can help to provide direction to policy makers. Local governments have decided to keep prices artificially high in some municipalities. This is a policy choice that society has so far accepted. Municipalities that want more affordable housing for their

\(^{47}\) See (Glaeser and Gyourko 2002).
citizens need only follow a simple heuristic: issue more permits, allow more buildings, and prices will come down.
7 – References


Data Sources

1) Median Housing Prices from the Canadian Real Estate Association’s MLS database. Data is proprietary. Contact author for further information.

2) Housing Start data from the Canada Mortgage and Housing Corporation (CMHC). Contact author for further information about monthly data. Yearly data is publically available:

3) Vancouver HPI from Teranet. [available online]
   http://www.housepriceindex.ca/
   Go to Download Historical Data (.xls)

4) CPI Data from Statscan Table 326-0020. [available online]
   http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=3260020&paSer=&pattern=&stByVal=1&p1=1&p2=37&tabMode=dataTable&csid=

5) The Interest Rate Data is from the Bank of Canada’s website but the data source is from the CMHC. [available online]

6) Population Data from Statscan Table 282-0109. For a list of municipalities measured as the population of ‘Vancouver’ see:

7) Agricultural Land Reserve Data. [available online]
   http://www.metrovancouver.org/planning/development/agriculture/AgricultureDocs/AgricultureBackgrounderMarch09.pdf
8) Foreign languages spoken at home comes from BC Stats. [available online]
http://www.bcstats.gov.bc.ca/Files/14dd8ee0-e9d3-4614-8d07-d673dce01cb9/2011CensusProfile-BritishColumbiaCMAsandCAs.xlsx

9) Residential Building Permits comes from BC Stats. [available online]
http://www.bcstats.gov.bc.ca/Files/6f0cb448-268d-41d7-81a2-f4b654a38494/BuildingPermits-Monthlyfrom2003.xlsx

10) Income data from Statscan Table 282-0068. [available online]
http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=2820069&paSer=&pattern=&stByVal=1&p1=1&p2=37&tabMode=dataTable&csid=
8 - Figures

Figure 1:
Lower Mainland Housing Price Index

Figure 2:
The Relationship between HSEs and PSEs

R² = 0.859
Figure 3:
Rankings of HSEs and PSEs

Figure 4:
The Relationship between HSEs & Long-Run Price Growth

\[ R^2 = 0.564 \]
\[ \text{Corr}(\text{Price Growth}, \text{HSE}) = -0.95 \]
Figure 5: The Relationship between HSEs and ASEs

Figure 6: Residuals from 2SLS
Figure 7: Residuals from 2SLS with Interest Rate

Figure 8: Residuals from Quasi-Differenced 2SLS
Figure 9:
Residuals from Quasi-Differenced 2SLS with Interest Rate

Figure 10:
Relationship between Price Growth and the ALR

R² = 0.094
Corr(Price Growth, ALR %)=-0.31
Figure 11: Relationship between Price Growth and Ethnic Population

Figure 12: Relationship between Per Capita Permits and HSEs
Figure 13: Relationship Between Per Capita Permits and Price Growth

\[ R^2 = 0.36 \]
\[ \text{Corr(Price Growth, Per Capita Permits)} = -0.6 \]

Average Yearly Permits as a % of Municipal Population

Figure 14: Map of Lower Mainland Municipalities
### Table 1: Variables in the Supply Equation

<table>
<thead>
<tr>
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<th>Housing Price</th>
<th>Material Costs</th>
<th>Labour Costs</th>
<th>Interest Rate</th>
<th>Lagged Prices</th>
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<tr>
<td>(Malpezzi 2001)</td>
<td>X</td>
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<td>(Goodman 2008)</td>
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### Table 2: Variables in the Demand Equation

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<th>Stock Adjustment</th>
<th>Interest Rate</th>
<th>Other Prices</th>
<th>Ownership rate</th>
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<td>(Wang et al 2012)</td>
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<td>(Malpezzi 2001)</td>
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<td>(Goodman 2008)</td>
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### Table 3: Municipal Summary Statistics

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<tr>
<th></th>
<th>Burnaby</th>
<th>Coquitlam</th>
<th>Delta</th>
<th>Maple Ridge</th>
<th>New Westminster</th>
<th>North Vancouver</th>
<th>Port Coquitlam</th>
<th>Port Moody</th>
<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
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<tr>
<td>Land area</td>
<td>90.09</td>
<td>121.68</td>
<td>183.78</td>
<td>206.89</td>
<td>15.4</td>
<td>11.95</td>
<td>28.79</td>
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<td>128.69</td>
<td>317.4</td>
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<td>Population Growth 2001-2011</td>
<td>15.1%</td>
<td>12.0%</td>
<td>3.0%</td>
<td>20.4%</td>
<td>20.7%</td>
<td>8.8%</td>
<td>9.9%</td>
<td>38.5%</td>
<td>15.9%</td>
<td>34.5%</td>
<td>10.6%</td>
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<td>Total number of occupied private dwellings 2001</td>
<td>74,000</td>
<td>40,220</td>
<td>32,780</td>
<td>22,590</td>
<td>26,025</td>
<td>20,710</td>
<td>17,765</td>
<td>8,640</td>
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<td>256,095</td>
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<td>Total number of occupied private dwellings 2006</td>
<td>78,030</td>
<td>41,235</td>
<td>36,565</td>
<td>24,935</td>
<td>27,045</td>
<td>21,345</td>
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<td>46,555</td>
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<td>Housing Stock Growth 2001-2011</td>
<td>17.4%</td>
<td>13.3%</td>
<td>5.0%</td>
<td>24.1%</td>
<td>17.5%</td>
<td>10.0%</td>
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<td>47.9%</td>
<td>19.7%</td>
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<td>12.1%</td>
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<td>$229,950</td>
<td>$299,500</td>
<td>$199,000</td>
<td>$198,100</td>
<td>$285,000</td>
<td>$213,200</td>
<td>$245,750</td>
<td>$220,000</td>
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<td>$253,375</td>
<td>$325,000</td>
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<tr>
<td>Median Housing Prices December 2012</td>
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<td>$513,500</td>
<td>$464,000</td>
<td>$375,790</td>
<td>$339,000</td>
<td>$640,000</td>
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<td>$568,000</td>
<td>$380,000</td>
<td>$635,000</td>
<td>$890,000</td>
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<tr>
<td>Housing Price Growth 2001-2011</td>
<td>86.0%</td>
<td>123.3%</td>
<td>54.5%</td>
<td>88.8%</td>
<td>66.6%</td>
<td>116.9%</td>
<td>92.8%</td>
<td>77.8%</td>
<td>130.9%</td>
<td>74.3%</td>
<td>150.6%</td>
<td>173.8%</td>
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<td>Ratio of Price Growth to Housing Stock Growth</td>
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<td>10.3</td>
<td>18.3</td>
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<td>Housing Price Growth Inflation Adjusted 2001-2011</td>
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<td>96.6%</td>
<td>43.0%</td>
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### Table 4: HSEs - OLS

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<tr>
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### Table 5: HSEs – OLS with real interest rate variable

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<th>Vancouver</th>
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Table 6: HSEs – 2SLS

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Table 7: HSEs – 2SLS with real interest rate variable

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<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
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Table 8: PSEs – 2SLS

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Table 9: PSEs – 2SLS with real interest rate variable

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Table 10: ASEs – 2SLS

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<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
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Table 11: ASEs – 2SLS with real interest rate variable

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Table 12: Relevance and Exogeneity of ERs

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Table 13: Tests for Serial Correlation

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<th>Port Moody</th>
<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
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<td>0.306</td>
<td>0.063</td>
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<td>0.130</td>
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<td>0.121</td>
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<td>0.105</td>
<td>0.263</td>
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<td>0.191</td>
<td>0.339</td>
<td>0.082</td>
<td>0.098</td>
<td>0.130</td>
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<td>1.625</td>
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Table 14: HSEs – Quasi-differenced 2SLS

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<th>New Westminster</th>
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<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
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</tr>
</tbody>
</table>

Table 15: HSEs – Quasi-differenced 2SLS with real interest rate variable

<table>
<thead>
<tr>
<th></th>
<th>Burnaby</th>
<th>Coquitlam</th>
<th>Delta</th>
<th>Maple Ridge</th>
<th>New Westminster</th>
<th>North Vancouver</th>
<th>Port Coquitlam</th>
<th>Port Moody</th>
<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>0.34</td>
<td>0.27</td>
<td>0.10</td>
<td>0.34</td>
<td>0.20</td>
<td>0.23</td>
<td>0.28</td>
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<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
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<td>0.00</td>
<td>0.00</td>
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</tr>
</tbody>
</table>
Table 16: ASEs – Quasi-differenced 2SLS

<table>
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<th>Coquitlam</th>
<th>Delta</th>
<th>Maple Ridge</th>
<th>New Westminster</th>
<th>North Vancouver</th>
<th>Port Coquitlam</th>
<th>Port Moody</th>
<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>

Table 17: ASEs – Quasi-differenced 2SLS with real interest rate variable

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<th>Burnaby</th>
<th>Coquitlam</th>
<th>Delta</th>
<th>Maple Ridge</th>
<th>New Westminster</th>
<th>North Vancouver</th>
<th>Port Coquitlam</th>
<th>Port Moody</th>
<th>Richmond</th>
<th>Surrey</th>
<th>Vancouver</th>
<th>West Vancouver</th>
</tr>
</thead>
<tbody>
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<td>0.01</td>
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<tr>
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<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
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</tr>
</tbody>
</table>