

The determinants of housing supply responsiveness in New Zealand regions

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Abstract

Auckland and many other fast-growing regions in New Zealand have experienced falling housing affordability in recent decades. While a range of factors contribute to house price increases, unresponsive housing supply in response to growing demand is a fundamental cause of sustained increases.

In response to rising prices and lagging construction, policymakers have responded with a range of measures to relax land use regulations that may prevent new homes from being built and increase the availability of developable land. This includes changes to the Resource Management Act to reduce uncertainty when consenting new homes, a rewrite of Auckland's zoning code through the Auckland Unitary Plan, and investments in infrastructure to expand subdivision opportunities.

The theory behind these changes is that permissive land use regulations and increased availability of developable land will enable housing supply to better respond to demand and hence moderate price increases. However, this approach is informed to a significant degree by international literature, rather than local evidence of the effect that these factors have on housing supply.

This paper fills this gap in the evidence base by investigating these relationships using New Zealand data for the 2001-2016 period. It asks:

1. To what degree do new housing consents respond to changes house prices at a regional level?
2. What impact do geographic constraints on developable land and delays in obtaining resource consent for new dwellings have on regional housing supply responsiveness?

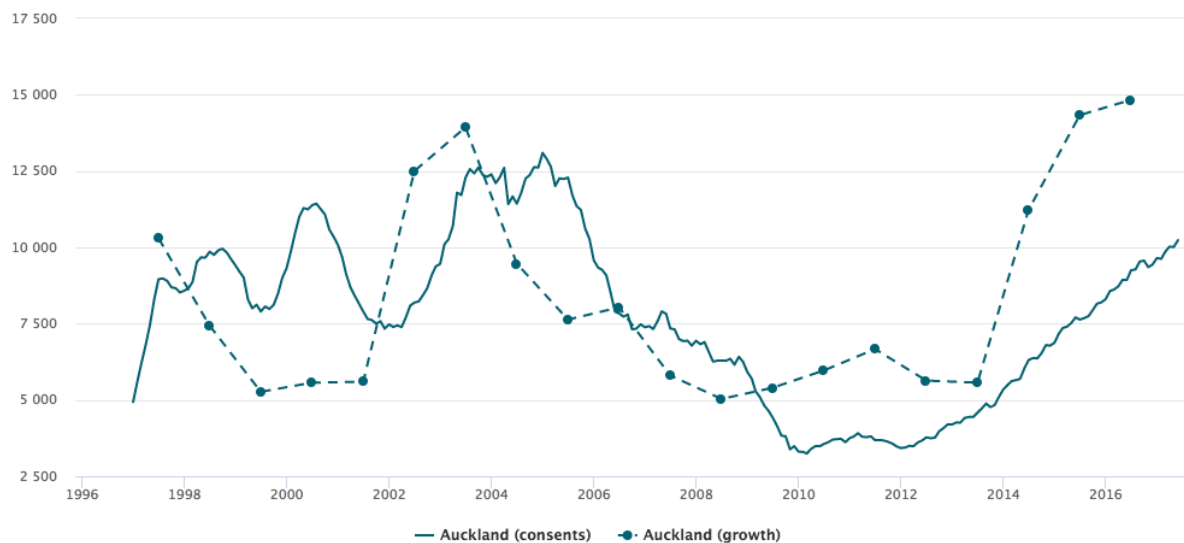
Acknowledgments: I appreciate the assistance of Ryan Greenaway-McGrevy (University of Auckland) in helping guide this research and assistance from colleagues at MRCagney to compile some of the data. In addition, I note that this paper has benefitted from a number of conversations with people in New Zealand's economics community and the broader housing policy and planning community. Any remaining errors are the fault of the author.

1. Introduction

Auckland and many other fast-growing regions in New Zealand have experienced falling housing affordability in recent decades. While a range of factors contribute to house price increases, unresponsive housing supply in response to growing demand is a fundamental cause of sustained increases (Andrews, Caldera and Johansson, 2011).

Are New Zealand's housing affordability problems due in part to sluggish housing supply responsiveness? A casual examination of the data suggests that this may be the case. As shown in the following chart, since 2009 Auckland has added more new households than new consented dwellings. This has coincided with a large run-up in house prices.

Figure 1: New dwelling consents compared to growth in the number of households in Auckland (MBIE, 2017)



In response to rising prices and lagging construction, policymakers have responded with a range of measures to relax land use regulations that may prevent new homes from being built and increase the availability of developable land. This includes changes to the Resource Management Act (the framework legislation for land use regulation) to reduce uncertainty

when consenting new homes, a rewrite of Auckland's zoning code through the Auckland Unitary Plan, and investments in infrastructure to expand subdivision opportunities.

The theory behind these changes is that permissive land use regulations and increased availability of developable land will enable housing supply to better respond to demand and hence moderate price increases. However, this approach is informed to a significant degree by international literature, rather than local evidence of the effect that these factors have on housing supply.

In this paper I attempt to fill this gap in the evidence base by investigating these relationships using New Zealand data for the 2001-2016 period. My primary research questions are as follows:

- To what degree do new housing consents respond to changes house prices at a regional level?
- What impact do geographic constraints on developable land and delays in obtaining resource consent for new dwellings have on regional housing supply responsiveness?

The remainder of this paper is structured as follows. Section 2 presents a brief literature review of previous approaches to estimate housing supply responsiveness. Section 3 describes the data that I have used for estimation. Section 4 describes my econometric methodology, and Section 5 highlights the results. To conclude, Section 6 interprets these results, identifies some limitations, and highlights considerations for further research. A technical appendix provides further information on the underlying data and several technical considerations that I do not fully address in the body of the paper.

2. Literature review

A variety of papers investigate the determinants and impacts of housing supply responsiveness in various countries, including New Zealand. Different papers adopt different approaches to dealing with the time series properties of house prices and the potential for endogeneity between prices and new construction.

Caldera and Johansson (2013) estimate housing supply elasticities at the national level for 21 OECD countries, including New Zealand, over the mid-1980s to mid/late-2000s period. For each country, they estimate long-run price and investment equations in an error-correction framework. They find that housing supply (measured as gross fixed capital formation in housing) is highly responsive to increased demand in the US, Canada, Sweden, and Denmark, while New Zealand exhibits intermediate levels of supply responsiveness.

Mayer and Somerville (2000a) estimate the responsiveness of housing supply for US metropolitan areas over the 1985-1999 period. They use a panel modelling framework that models new housing construction as a function of changes in house prices in the current and recent quarters. Changes in house prices are used in the model in response to evidence that house prices are non-stationary. Several papers apply the same basic modelling approach to estimate housing supply responsiveness in Australian regions (McLaughlin, 2011; Ong *et al*, 2017). Mayer and Somerville's model treats house price changes as exogenous to supply.

Grimes and Aitken (2010) adopt a different approach to addressing non-stationarity in house prices. They observe that, in a competitive construction market, the price for new homes will be a function of construction costs plus land prices. They therefore estimate the responsiveness of supply to house price increases in New Zealand regions over the 1991-2004 period by modelling new dwelling consents as a function of the level of house prices, construction costs, and land prices. Due to concerns about the endogeneity of prices and

supply, they use a two-stage least squares (2SLS) estimation procedure to instrument for price variables. Grimes and Aitken also show that regions with lower supply responsiveness tend to experience larger spikes in prices in response to demand shocks.

A number of papers have demonstrated that restrictive land use regulations and geographic constraints reduce the responsiveness of housing supply, although these relationships have not been proven in the New Zealand context. Mayer and Somerville (2000b) extend their earlier model to show that growth controls and delay in obtaining consent result in lower housing supply responses in US cities. Ong *et al* (2017) show that Australian regions where more land is steeply sloping or already developed experience slower supply responses.

Saiz (2010) and Paciorek (2013) find that both restrictive land use regulations and a shortage of developable land reduce housing supply responsiveness in US cities. Paciorek further finds that delays in obtaining consent have a larger negative impact on supply than other types of land use regulations. While these papers use a different modelling approach, both consider the potential for endogeneity between house prices and supply and therefore instrument prices with measures of exogenous labour demand shocks and migration shocks.

Finally, both Saiz (2010) and Mayer and Somerville (2000b) consider the possibility that land use regulations are in fact endogenous to housing demand or supply. This may occur if, for instance, voters in high-price areas prefer tighter regulations to minimise risks to their property values, or if voters in declining areas prefer looser regulations to encourage growth. They therefore use instrumental variables to control for the potential endogeneity of regulations, finding that tighter land use regulations have a causal negative effect on supply responsiveness.

Further evidence of the causal impact of land use regulations is provided by Mayo and Sheppard (1996) and Jackson (2016), who find that the adoption of tighter land use regulations in Malaysia and Californian regions, respectively, was followed by reductions in the rate of new construction.

3. Data

To analyse housing supply responsiveness at the regional level I gathered quarterly data on new dwelling consents, housing stock, house prices, construction costs, and land values for all New Zealand territorial local authorities (TLAs) from 2001Q2 to 2016Q2. I excluded five TLAs (Ashburton, Christchurch, Selwyn, Waimakariri, and Waipa) that were either affected by earthquakes or missing data, leaving me with 61 quarters of data for 61 TLAs.

I then constructed measures of delay in processing resource consents (based on Ministry for the Environment data) and geographical constraints on development (based on Land Information New Zealand data on land titles and terrain), which are hypothesised to influence housing supply responsiveness.

Finally, to deal with potential endogeneity between new housing construction and prices, I constructed several measures of exogenous demand shocks that may affect prices without affecting supply. These included a measure of labour demand shocks at a local level (*a la* Bartik, 1991), a measure of immigration shocks at a local level (analogous to the labour demand shock), and an income level instrument constructed along similar lines.

The following table describes the variables used in this analysis, including how I have transformed or created specific variables.

Table 1: Source or derivation of model variables

Variable	Description / source
<i>Measures of housing supply</i>	
HC _{i,t}	<p>Consents for new dwellings in TLA i in quarter t.</p> <p>This was sourced from Statistics New Zealand (SNZ, 2017a) data on building consents. No reliable measure of dwelling completions is available, but I note that given various time lags in housing development, consents are more likely to exhibit a contemporaneous response to house price increases than completions.</p>
H _{i,t}	<p>Estimated housing stock in TLA i in quarter t.</p> <p>This was sourced from property sales data published on the Ministry of Business, Innovation and Employment (MBIE, 2017) property value portal.</p>
<i>Measures of house prices and costs</i>	
HP _{i,t}	<p>Average house price sold in TLA i in quarter t, adjusted for changes in the characteristics of houses built over the period of the analysis.</p> <p>Average house prices for 2016 Q4 were sourced from MBIE (2017), and back-casted using the sales price to appraisal ratio (SPAR) index published by MBIE (2017).</p>
LV _{i,t}	<p>Median value of residential sections in TLA i in quarter t, adjusted for changes in the characteristics of residential sections over the period of the analysis.</p> <p>Data on average land value per residential dwelling is available from MBIE (2017), but only for quarters when ratings valuations were conducted. As a result, I tested two approaches to estimating average land value per section. The first approach simply applied linear interpolation between valuation periods, while the second approach used a SPAR index for land values to back-cast the series from the date of the most recent valuation. As discussed in the technical appendix, both approaches produce similar results. I have used the second approach in this analysis.</p>
CC _{i,t}	<p>Cost to build a new dwelling in TLA i in quarter t.</p> <p>Average build cost per dwelling was sourced from SNZ (2017a)'s data on building consents for new residential dwellings, which provides information on the total value of consents, total floor area, and number of consents. To control for changes in the size of dwellings over time (but not other quality changes), I calculated the average cost per square metre of floor space for previous quarters and multiplied this by the average size of new dwellings consented in 2016.</p>
<i>Geography and regulatory delay variables</i>	
DL _i	<p>Total quantity of developable land in TLA i.</p> <p>This variable was calculated by applying GIS analysis to Land Information New Zealand parcel and digital elevation data (LINZ, 2013). The average slope for the longest line across</p>

	<p>each parcel was calculated.¹ Water and stream-bed parcels were excluded, as were parcels with an average slope over 15% (following Saiz, 2010). Finally, I summed up the total quantity of developable land in each TLA.</p>
$B_{i,t}$	<p>The share of total developable land in TLA i that is built out at quarter t.</p> <p>Following Paciorek (2013), I first calculate the total number of ‘development slots’ in each TLA by dividing DL_i by the average gross land area per dwelling in the Auckland city centre as at the 2013 Census (approximately 170m² per dwelling). Then I calculated the buildout ratio by dividing the number of dwellings $H_{i,t}$ by this figure.</p> <p>Hence $B_{i,t} = H_{i,t} * 170 / DL_i$</p>
T_i	<p>The average share of resource consents processed within statutory timeframes in TLA i, in the early 2000s.</p> <p>This variable was calculated using data from the 2001/02, 2003/04, and 2005/06 RMA Survey of Local Authorities published by the Ministry for the Environment (MfE, 2003, 2005, 2007).² I summed up the number of consents that were processed outside of statutory timeframes set by the RMA across the three surveys and divided this by the total number of consents processed during this period.</p> <p>This therefore measures the likelihood of developments experiencing unexpected regulatory delay in different TLAs. As discussed in the technical appendix, it is correlated with other, more recent measures of regulatory restrictiveness, suggesting that differences between TLAs on this measure reflect persistent differences in regulatory practices.</p>
<i>Instruments for house prices</i>	
$Bartik_{i,t}$	<p>A measure of exogenous labour demand shocks affecting TLA i in quarter t.</p> <p>I calculated the labour demand shock using the procedure outlined in Bartik (1991), which is explained further in the technical appendix. The logic behind this measure is that a national increase in employment in a given industry is likely to reflect a positive shock to labour demand in that industries, rather than local factors. Hence positive shocks to national employment in industries that are concentrated in a given TLA provide an indication of the degree to which those TLAs are experiencing labour demand shocks.</p> <p>I constructed this measure using SNZ (2017b) data on employment by industry (2-digit ANZSIC06 codes) and TLA for the 2000-2016 period. As employment data was only available on an annual basis (at the first quarter), I interpolated shocks for intermediate quarters.</p>
$Migration_{i,t}$	<p>A measure of exogenous immigration shocks affecting TLA i in quarter t.</p> <p>I calculated the migration shock using the approach outlined in Paciorek (2013), which is explained in the technical appendix. The logic behind this measure is that a rise in migrant</p>

¹ I appreciate the assistance of Saeid Adli (MRCagney) in calculating parcels’ average slope.

² I appreciate the assistance of Jess Philips (MfE) for providing this data in easy-to-use spreadsheet form.

	<p>inflows from a given country is likely to reflect factors specific to that country, eg a change in the political or economic climate that encourages emigration, rather than local factors. Due to chain migration patterns, they are likely to settle in areas that already have a high share of previous migrants.</p> <p>I used SNZ (2013) data on residents' birthplaces reported on the 2001, 2006, and 2013 Census to estimate the share of people in each TLA that originate from each overseas country. Population shares were interpolated between Census dates. I used quarterly data on inwards migration by non-New Zealand citizens, broken down by country of origin and TLA destination in New Zealand, to calculate quarterly migrant inflows from each country and hence calculate quarterly shocks. This data was sourced from a custom data request to SNZ.</p>
Income _{i,t}	<p>A measure of exogenous income shocks affecting TLA <i>i</i> in quarter <i>t</i>.</p> <p>I calculated this measure using the broad approach described in Bartik (1991). However, instead of applying it to employment changes, I estimated per-worker income levels using SNZ's (2017c) quarterly LEED data on labour income and employment at the level of NZ regions and one-digit ANZSIC06 industries. I took the natural logarithm of the resulting measure.</p>

The following charts show how model variables have evolved for Auckland, which has experienced fast growth over this period, and Invercargill, which has grown slowly.

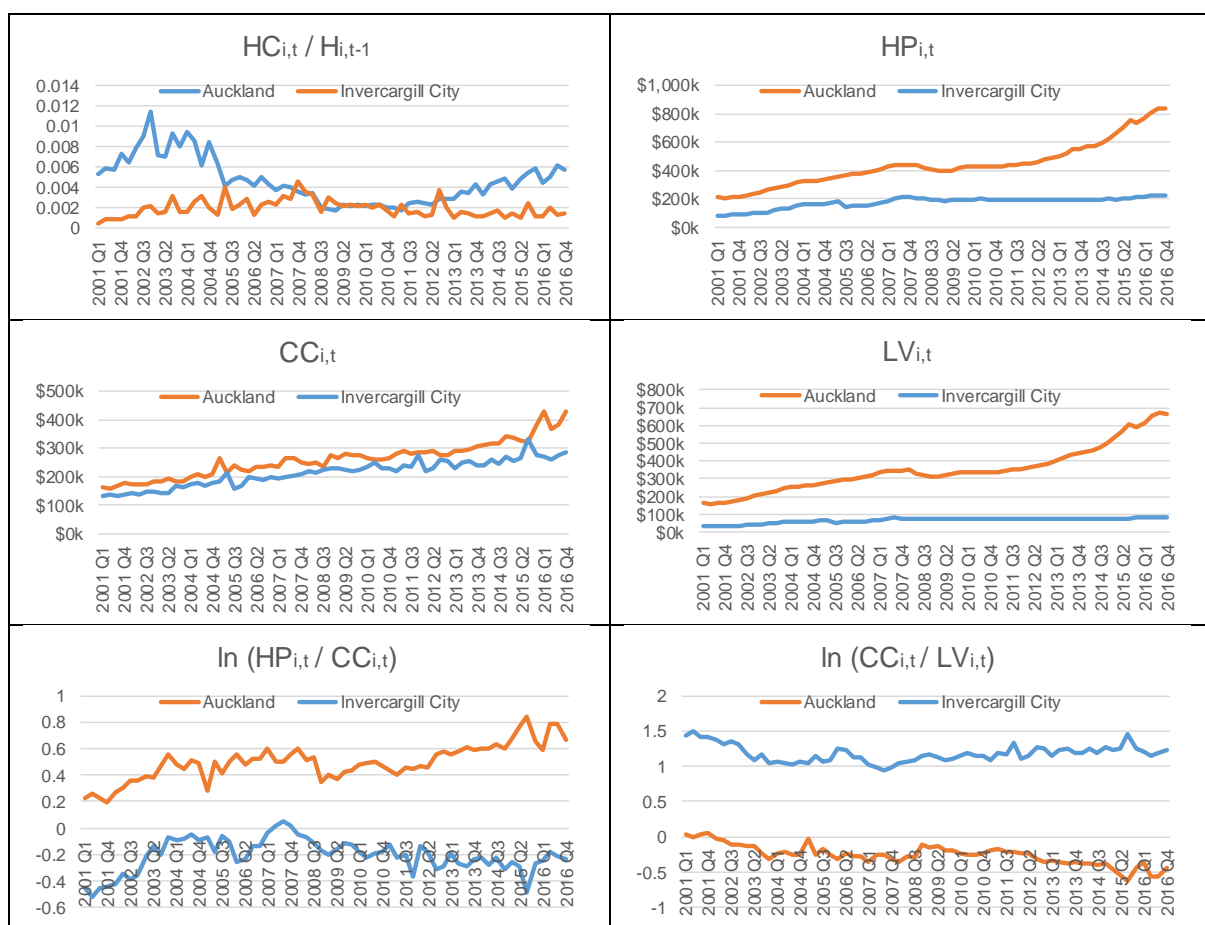
Descriptive statistics for the full dataset are provided in the technical appendix. The charts highlight some key time-series qualities of the data:

- In both cities, house prices, construction costs, and land values have risen over this period, but the pattern of increases varies between locations. In Auckland, the ratio of house prices to construction costs has risen throughout the period, but in Invercargill, prices have not increased significantly in the second half of the period.
- In both prices, house prices and land prices appear to rise in a similar pattern, suggesting that land values may adjust alongside house prices.

- The ratio of new dwelling consents to dwelling stock appears to have fallen and then risen in Auckland over this period, but it does not appear to have followed any clear trend in Invercargill. The average level of consents to stock is higher in Auckland.

Taken together, these charts indicate that model variables have the potential to exhibit non-stationary behaviour. Several model variables appear to be potentially cointegrated, in particular the land value and house price variables.

Figure 2: Model variables for Auckland (fast growth) and Invercargill (slow growth)



4. Methodology

I employed a panel regression model to estimate housing supply responsiveness at the TLA level. My modelling approach is informed by a simple economic theory about the behaviour of housing developers: that they will choose to supply more housing if prices rise relative to

the cost of supply, including both construction costs and land costs. Grimes and Aitken (2010) and Paciorek (2013) provide formal models of this relationship, which I draw upon to inform my choice of model specification.

Prior to specifying and estimating an econometric model, it was necessary to address two issues identified in the previous research: the likelihood that some model variables are non-stationary, and the potential for endogeneity between house prices and housing supply.

4.1. Stationarity and cointegration testing

Mayer and Somerville (2000a) and Grimes and Aitken (2010) observe that house prices tend to be non-stationary, meaning that their mean, variance, and/or covariance between adjacent terms may change over time. A visual inspection of data for selected New Zealand TLAs (Auckland and Invercargill) suggests that the average level of house prices, construction costs, and land prices has changed over time.

The rate of new housing construction (defined as $HC_{i,t} / H_{i,t-1}$) may also be non-stationary. It appears to have wandered around in Auckland, but less so in Invercargill and other TLAs.

I therefore conduct four alternative panel unit root tests on key model variables to understand whether they are stationary or non-stationary:

- The Levin-Lin-Chu (LLC) test, with and without a time trend. LLC tests whether there is a common unit root for all TLAs in the panel.
- The Im-Pesaran-Shin (IPS) test, again with and without a time trend. IPS tests whether any individual TLAs in the panel exhibit a unit root.

The number of lags was selected with the Schwarz information criterion (SIC). As the null hypothesis for these tests is that the variable contains a unit root, a p-value below a given

critical value (say 5%) indicates that the variable is stationary. The following table summarises the results, with tests that did not reject a unit root at either the 1%, 5%, or 10% level highlighted in bold.

The rate of new housing construction is stationary across all TLAs, as shown by the low p-value for each test. By contrast, the natural log of house prices and the natural log of construction costs are non-stationary in some, but not all, TLAs, as shown by the high p-values for IPS tests these variables. However, the first difference of house prices is stationary, in line with Mayer and Somerville (2000a)'s findings. Furthermore, all four tests indicate a rejection of a unit root in the ratio of house prices to construction costs [$\ln (PH_{i,t} / CC_{i,t})$].

The last result is important as it suggests that it is possible to model new housing supply as a function of the relationship between the level of house prices and the level of construction costs. Paciorek (2013) employs this approach in his analysis of US cities, but Grimes and Aitken (2010) have previously argued that this approach is not sufficient as house prices are cointegrated with both construction costs *and* land values.

As Grimes and Aitken analysed New Zealand data, it is worth considering why my findings may be different. One obvious difference is that my data includes the post-GFC period, when house price growth slowed in many TLAs, with the notable exception of Auckland. During this period, house prices have not risen significantly relative to construction costs, meaning that $\ln (PH_{i,t} / CC_{i,t})$ may be stationary. Arithmetically, this also seems to imply that land values have not risen relative to construction costs in most TLAs.

Table 2: Unit root tests

Variable	LLC no trend		LLC trend		IPS no trend		IPS trend	
	statistic	p-value	statistic	p-value	statistic	p-value	statistic	p-value
$\ln HP_{i,t}$	-16.8958	0.0000	-7.56401	0.0000	-10.2151	0.0000	2.30451	0.9894
$\ln CC_{i,t}$	-7.45006	0.0000	-30.0125	0.0000	-0.59199	0.2769	-27.0226	0.0000
$\ln LV_{i,t}$	-17.7215	0.0000	-7.37574	0.0000	-11.1431	0.0000	2.09836	0.9821
$\ln (PH_{i,t} / CC_{i,t})$	-7.23789	0.0000	-10.7312	0.0000	-9.44686	0.0000	-8.08734	0.0000
$\ln (CC_{i,t} / LV_{i,t})$	-7.70587	0.0000	-10.7899	0.0000	-9.33136	0.0000	-7.85712	0.0000
$\ln (HP_{i,t} / HP_{i,t-1})$	-72.0149	0.0000	-68.963	0.0000	-70.9553	0.0000	-68.5076	0.0000
$HC_{i,t} / H_{i,t-1}$	-11.1913	0.0000	-20.9583	0.0000	-12.915	0.0000	-19.1681	0.0000
$Bartik_{i,t}$	-3.40152	0.0003	6.24921	1.0000	-7.61785	0.0000	0.69954	0.7579
$Migration_{i,t}$	8.98881	1.0000	10.9566	1.0000	3.33174	0.9996	-0.67134	0.2510
$Income_{i,t}$	-21.7531	0.0000	21.6998	1.0000	-8.31092	0.0000	18.2337	1.0000

A final important finding is that none of my candidates for instrumental variables – $Bartik_{i,t}$, $Migration_{i,t}$, or $Income_{i,t}$ – are stationary, as shown in the high p-values in the last three rows of the above table. At first blush, this seems like it would pose a serious problem for estimation. However, if these variables are cointegrated with $\ln (PH_{i,t} / CC_{i,t})$, then the OLS estimator of the relationship between $\ln (PH_{i,t} / CC_{i,t})$ and the proposed instruments is likely to be super-consistent, rather than biased. If this is the case, then it would be acceptable to use these instruments in the first stage of a panel instrumental variables model.

I therefore use a set of Pedroni residual cointegration tests to investigate whether these variables are cointegrated. Tests were conducted with and without a time trend. As shown in the following table, the majority of tests suggest that these variables *are* cointegrated – ie low p-values indicate that we can reject the null hypothesis of no cointegration. Similarly, each of the four LLC and IPS tests described above indicates a rejection of the null hypothesis that there is a unit root in the residuals of the first stage regression of the instruments on $\ln (PH_{i,t} / CC_{i,t})$.

Table 3: Cointegration tests for regression of instrument candidates on $\ln (PH_{i,t} / CC_{i,t})$

	Pedroni (Engle Granger) test, no trend		Pedroni (Engle Granger) test, trend	
Test	Statistic	p-value	Statistic	p-value
Alternative hypothesis: common AR coefs. (within-dimension)				
Panel v-Statistic	3.719924	0.0001	-1.1544	0.8758
Panel rho-Statistic	-14.1991	0.0000	-13.2996	0.0000
Panel PP-Statistic	-17.048	0.0000	-18.8681	0.0000
Panel ADF-Statistic	-12.1365	0.0000	-14.3121	0.0000
Alternative hypothesis: common AR coefs. (within-dimension); weighted				
Panel v-Statistic	-0.87764	0.8099	-5.38453	1.0000
Panel rho-Statistic	-9.26833	0.0000	-8.35258	0.0000
Panel PP-Statistic	-12.7904	0.0000	-13.8886	0.0000
Panel ADF-Statistic	-8.68308	0.0000	-10.474	0.0000
Alternative hypothesis: individual AR coefs. (between-dimension)				
Group rho-Statistic	-10.051	0.0000	-8.15702	0.0000
Group PP-Statistic	-14.5517	0.0000	-14.3736	0.0000
Group ADF-Statistic	-8.16965	0.0000	-9.06888	0.0000

4.2. Econometric model specification

My basic econometric model is described in the following equation. I model the rate of new dwelling consents relative to building stock ($HC_{i,t} / H_{i,t}$) as a function of the ratio of house prices to construction costs [$\ln (HP_{i,t} / CC_{i,t})$]. The intuition behind this approach is that when prices are higher relative to build costs, developers have a stronger financial incentive to develop new housing.

I also include a TLA fixed effect (FE_i) to control for time-invariant factors that affect the level of new house supply in different regions, and a time fixed effect (FE_t) to control for time-varying effects that affect new house supply everywhere, such as changes in interest rates or credit conditions that reduce or increase the cost of obtaining financing for development.

I estimate this equation using a 2SLS panel model, as discussed further below.

Using the level of house prices relative to build costs, rather than quarterly differences in prices and build costs, means that the β coefficient can be interpreted as an estimate of long-run supply responsiveness, as any rise in consents resulting will persist until the ratio of prices to build costs returns to its average level.

Equation 1: Panel regression model of the housing supply response to higher prices

$$\frac{HC_{i,t}}{H_{i,t-1}} = \beta \ln(HP_{i,t}/CC_{i,t}) + FE_i + FE_t + \varepsilon_{i,t}$$

I extend the basic model to investigate *why* some TLAs have more responsive housing supply than others. I begin by interacting $\ln(HP_{i,t}/CC_{i,t})$ with T_i , which measures the share of consents that were delayed beyond statutory timeframes in the early 2000s. The interaction term therefore captures the degree to which increased delay in consent processing affect housing supply responsiveness.

Next, I interact $\ln(HP_{i,t}/CC_{i,t})$ with $B_{i,t}$, which measures the degree to which developable land is 'built out' in each TLA. Third, I added a further interaction between with an indicator variable for whether each TLA was a city council or district council, as city councils tend to be smaller in size and include less rural / peri-urban land.³ These interaction terms therefore capture the degree to which tighter geographic constraints or reduced availability of developable land affect housing supply responsiveness.

4.3. Addressing endogeneity between housing prices and supply

³ Auckland was difficult to classify. it contains a large urban area and hence is more built out than most district councils, but it also contains substantial rural and peri-urban areas. As a result, I tested two alternative specifications – one that coded Auckland as a district council, and one that coded it as a city council.

As noted in the literature, house prices and new housing supply may be endogenous. For instance, if there is a credible expectation that more homes will be consented in the near future, then prices may fall due to the expectation that there will be a larger supply of housing in the future. Alternatively, excessively high prices in a TLA may discourage people from moving there, which may reduce the number of new homes that are constructed. This may bias OLS estimates of housing supply responsiveness.

In order to address the potential for endogeneity, I investigate several instruments for the ratio of house prices to construction costs: $Bartik_{i,t}$, $Migration_{i,t}$, and $Income_{i,t}$. These instruments are well established in the US literature. Saiz (2010) and Paciorek (2013) find that $Bartik$ and migration shock variables are strong instruments for house prices in US cities, while Saiz also shows that these variables are exogenous. Similarly, Andrews, Sanchez and Johansson (2011) find that real house prices are strongly affected by households' disposable income in OECD countries. Furthermore, these variables should be exogenous to local housing supply by construction, as they exploit trends occurring in other regions that may also affect local demand for housing.

In order for variables Z to be valid instruments for X , they must satisfy two conditions:

- Instrument relevance: $Cov(Z, X) \neq 0$
- Instrument exogeneity: $Cov(Z, u) = 0$, where u are unknown factors that affect both X and outcome variable Y .

I therefore carry out two tests of instrument validity. First, I test the strength of my instruments by regressing them on $\ln(HP_{i,t} / CC_{i,t})$ and comparing the resulting F-statistic to the critical values set out in Stock and Yogo (2005). Second, as I have an overidentified model with more potential instruments than endogenous regressors, I can test for

instrument exogeneity using the Anderson-Rubin test. In this test, I estimate the econometric model described above using OLS, regress the set of instruments on the residuals from the model, and calculate the J-statistic by multiplying the resulting F-statistic by the number of instruments. If the J-statistic is below the relevant critical value from a χ^2 distribution then it indicates that the instruments are exogenous.

The following table summarises the results of these tests for my three instruments. These tests suggest that the instruments are strong and exogenous – ie they are relevant for use in estimating a 2SLS panel model.

Table 4: Tests for instrument validity

Test	Test statistic	Critical values at 5% significance level	Conclusion
Weak instruments test (Stock and Yogo) ⁴	201.564	13.91 (critical value for bias < 0.05) 22.30 (critical value for size distortion < 0.10)	Reject null hypothesis of weak instruments as F-stat exceeds both critical values
Instrument exogeneity test (Anderson-Rubin) ⁵	0.546	7.81 (critical value of a χ^2 distribution with df = 3)	Fail to reject instrument exogeneity as J-stat is below critical value

To estimate the panel IV models with interaction terms that I describe above, I save the fitted values $\ln(\widehat{HP}_{i,t}/CC_{i,t})$ from the first stage model and then interact them directly with the regulatory delay and geographic constraint variables in the second stage of the model. This is necessary in order to get accurate estimates of the effect of the interaction terms.

⁴ This test statistic is the F-statistic from the first stage regression described above. Critical values are obtained from Tables 5.1 and 5.2 in Stock and Yogo (2005).

⁵ This test statistic is the J-statistic, which is obtained by multiplying the F-statistic of 0.1819 by the number of instruments (3).

However, the standard errors from the second stage regression are biased. As a result, I used bootstrapping to obtain correct standard errors from my manual 2SLS procedure. This entails repeatedly re-estimating my manual 2SLS from data that was sampled from my original dataset, saving the coefficient estimates from the second stage, and calculating standard errors based on the distribution of coefficient estimates.⁶ I chose to bootstrap standard errors rather than re-estimate them analytically due to the fact that there are several factors to correct for, including bias arising from the manual 2SLS procedure and potential heteroscedasticity and autocorrelation in the residuals.

5. Overview of results

The following table summarises the results of 2SLS estimation of the above models.

Model 1 indicates that, on average, when house prices rise by 10% relative to build costs, it leads to a quarterly uptick in new dwelling consents equal to 0.185% of the current dwelling stock. This coefficient is statistically significant at the 5% level and practically significant. For instance, Hamilton currently has 50,000 dwellings and has consented an average of around 220 homes each quarter over the period. This model would imply that a 10% rise in house prices relative to build costs would lead to an additional 92 consents per quarter in Hamilton, which would equate to a 42% increase in the pace of consenting.

Model 2 indicates that the supply response to increased house prices (relative to build costs) is smaller in TLAs with more delay in processing resource consents. The interaction term is negative and statistically significant at the 5% level. In this model specification, the statistical significance of the $\ln (HP_{i,t} / CC_{i,t})$ term drops slightly, with a p-value of 0.052.

⁶ I implemented the bootstrap procedure in Stata, as EViews does not provide this method. I used 200 replications.

Model 3 indicates that the supply response to increased house prices is smaller in TLAs where more of the developable land is built out. Both interaction terms are negative and highly statistically significant, but the p-value of the $\ln(HP_{i,t} / CC_{i,t})$ term is again slightly above 0.05.

Models 4a and 4b indicate that this relationship holds true for both city councils (which tend to have higher buildout ratios to start with, as TLA boundaries are drawn more tightly around urbanised areas) and district councils (which usually include large rural or peri-urban areas). This difference is qualitatively similar regardless of whether I categorise Auckland as a district or city council.

Table 5: Econometric model estimation results

Dependent variable	HC _{i,t} / H _{i,t-1}														
Model	1			2			3			4a (Auckland=district)			4b (Auckland=city)		
Explanatory variables	Coeff	Std err	p-value	Coeff	Std err	p-value	Coeff	Std err	p-value	Coeff	Std err	p-value	Coeff	Std err	p-value
ln (HP _{i,t} / CC _{i,t})	0.0185	0.0086	0.0310	0.0200	0.0103	0.0520	0.0213	0.0111	0.0540	0.0227	0.0106	0.0320	0.0222	0.0102	0.0300
ln (HP _{i,t} / CC _{i,t}) x T _i				-0.0062	0.0022	0.0040	-0.0073	0.0022	0.0010	-0.0067	0.0022	0.0030	-0.0074	0.0022	0.0010
ln (HP _{i,t} / CC _{i,t}) x B _{i,t}							-0.0763	0.0100	0.0000						
ln (HP _{i,t} / CC _{i,t}) x B _{i,t} x City council										-0.0742	0.0104	0.0000	-0.0762	0.0098	0.0000
ln (HP _{i,t} / CC _{i,t}) x B _{i,t} x District council										-0.3964	0.0488	0.0000	-0.2883	0.0480	0.0000
TLA and quarter FE?	Yes			Yes			Yes			Yes			Yes		

Notes:

- (1) In all models, the variable for prices relative to build costs is instrumented with $Bartik_{i,t}$, $Migration_{i,t}$ and $Income_{i,t}$.
- (2) In models 2-4b, an interaction term between prices and delays in consenting in the early 2000s (T_i) is added.
- (3) In models 3-4b, an interaction term with the share of developable land built out in each TLA at time t ($B_{i,t}$) is also added.
- (4) Models 4a and 4b add interactions with variables for city and district councils. In model 4a, Auckland is coded as a district council; in model 4b, it is coded as a city council.
- (5) These model outputs were calculated in Stata using the `xtreg` command with TLA and quarter fixed effects to implement a manual 2SLS procedure. Curiously, Stata provided slightly different coefficient estimates for the interaction terms with $B_{i,t}$, relative to EViews. This difference was not practically significant and hence I have reported the Stata outputs to ensure consistency with the bootstrapped standard errors. However, this may bear further investigation.

6. Conclusions

To conclude, I briefly interpret what these results imply about housing supply responsiveness in growing urban areas, discuss the caveats and limitations associated with these results, and identify areas where further research is needed.

6.1. Interpretation of results

To illustrate the practical significance of these results, I use point estimates of coefficients from Models 3, 4a, and 4b to estimate housing supply response parameters for selected TLAs that include or border fast-growing urban areas. This has an element of out-of-sample prediction as I estimate responsiveness for three TLAs in the Greater Christchurch area that were excluded from the dataset used for model estimation.

The following table reports the predicted supply responsiveness for 16 TLAs that make up some of the largest and fastest-growing urban areas in New Zealand. Values have been fitted by multiplying the relevant model coefficients by T_i and 2016 Q2 values of $B_{i,t}$. To make these results meaningful, I also estimate the number of dwelling consents per quarter that would be expected in response to a 10% increase in house prices relative to build costs.

Some key implications from these estimates are as follows.

First, TLAs that are adjacent to major city councils and which experience 'spillover' development pressure, such as Selwyn and Waimakariri in Greater Christchurch, tend to have higher supply responsiveness than the core of the urban area. This is principally due to the greater availability of developable land in most peri-urban areas, but in some cases it also reflects differences in consenting delay.

Second, all three models produce similar results for most TLAs, with Models 4a and 4b tending to indicate higher supply responsiveness in city councils relative to Model 3. Auckland is a notable exception to this pattern. Model 4a suggests that Auckland has a considerably lower supply responsiveness than the Model 4b, as it is highly developed relative to most district councils but contains more rural or peri-urban land than most city councils. As there is a large practical difference between the two predictions of Auckland's supply responsiveness, it may be desirable to investigate this result further. At this stage it is not clear which model is more appropriate, eg in terms of goodness of fit.

Third, most urban or peri-urban TLAs have supply responsiveness below the predicted median level for all TLAs. The main exceptions are Waikato, Waipa, and Western Bay of Plenty, which have above-median responsiveness in all three specifications. This suggests that cities in New Zealand may face systematic difficulties in building more housing in response to increased demand.

Bringing urban areas up to the average supply responsiveness could lead to a large increase in the quantity of homes that are ultimately built. If, for instance, Auckland had median supply responsiveness, a 10% increase in house prices relative to build costs would lead to 926 to 969 additional quarterly consents, rather than the predicted rate of 581 to 849 (depending upon model specification). Similarly, if Hamilton had median supply responsiveness, a 10% increase in prices relative to costs would lead to 99 to 104 additional quarterly consents, rather than the predicted rate of 76 to 84.

Table 6: Predicted supply responsiveness for TLAs in major urban areas

TLA	Dwelling stock (2016 Q2)	Average quarterly consents	Predicted supply responsiveness			Predicted consents in response to a 10% increase in house prices relative to build costs		
			Model 3	Model 4a	Model 4b	Model 3	Model 4a	Model 4b
Auckland	469,986	1,864	0.0173	0.0124	0.0181	813	581	849
Christchurch City	137,073	549	0.0178	0.0194	0.0186	244	265	255
Selwyn District	17,255	176	0.0191	0.0204	0.0197	33	35	34
Waimakariri District	19,743	148	0.0199	0.0206	0.0202	39	41	40
Wellington City	66,972	202	0.0097	0.0115	0.0106	65	77	71
Lower Hutt City	35,487	47	0.0151	0.0167	0.0159	54	59	56
Porirua City	16,586	45	0.0178	0.0193	0.0186	30	32	31
Upper Hutt City	14,844	40	0.0184	0.0199	0.0192	27	30	29
Hamilton City	50,316	219	0.0152	0.0167	0.0160	76	84	80
Waikato District	20,249	97	0.0202	0.0213	0.0208	41	43	42
Waipa District	16,252	87	0.0207	0.0214	0.0210	34	35	34
Tauranga City	48,027	253	0.0136	0.0153	0.0143	65	74	69
Western Bay of Plenty District	15,783	75	0.0202	0.0211	0.0207	32	33	33
New Plymouth District	28,264	87	0.0203	0.0202	0.0201	57	57	57
Whangarei District	31,214	133	0.0195	0.0201	0.0197	61	63	62
Queenstown-Lakes District	15,339	145	0.0186	0.0191	0.0186	29	29	29
<i>Median supply responsiveness (applied to Hamilton)</i>	<i>50,316</i>		<i>0.0197</i>	<i>0.0206</i>	<i>0.0201</i>	<i>99</i>	<i>104</i>	<i>101</i>
<i>Median supply responsiveness (applied to Auckland)</i>	<i>469,986</i>		<i>0.0197</i>	<i>0.0206</i>	<i>0.0201</i>	<i>926</i>	<i>969</i>	<i>944</i>

6.2. Caveats and limitations

These results are subject to several caveats and limitations.

To begin, further work is required to better understand the property of my instrumental variables, and ensure that they are indeed valid. Three considerations arose when calculating instruments and estimating this model. First, these instruments may be subject to measurement error, eg due to the fact that it was necessary to join together two different sources of data on migrant populations and migration flows when constructing the $\text{Migration}_{i,t}$ variable. Second, there is cross-sectional correlation in the $\text{Bartik}_{i,t}$ and $\text{Income}_{i,t}$ variables. Many New Zealand regions appear to be subject to common labour demand shocks. It is unclear whether this affects estimation. Third, given the finding that the instruments are cointegrated with the ratio of house prices to build costs, it may be advisable to further investigate the consequences of including or excluding some instruments when estimating the model.

A second caveat relates to measurement error in my regulatory delay variable. In the technical appendix, I report supplementary analysis showing that this measure is positively correlated with more recent attempts to estimate the restrictiveness of land use regulation in a sub-set of TLAs. This suggests that this measure is valid, but further work is needed to ensure that it is robust.

A third caveat is around the exogeneity (or potential lack thereof) of the variables for regulatory delay and the availability of developable land. Both Mayer and Somerville (2000b) and Saiz (2010) observe that land use regulations may be endogenous to prices and therefore instrument for regulation to estimate its causal effect on prices. In the technical appendix, I investigate this issue further, finding that my regulatory delay measure is

uncorrelated with exogenous geographical factors that may influence prices, such as geographic constraints and high sunshine hours. This suggests that endogeneity of land use regulations is less likely to be a problem in the New Zealand context, but this tentative finding bears further investigation.

Given that my measure of the availability of developable land is based on both geographic constraints at a TLA level *and* the current housing stock, it could also be endogenous.⁷ I note that Paciorek (2013) handled this issue by instrumenting this variable using his Bartik and migration shock variables, which may be worth investigating in future work.

6.3. Areas for further research

In this paper, I estimate the responsiveness of housing supply at a regional level and go some way to explaining why supply responsiveness varies between different areas.

However, I do not explore the *consequences* of higher or lower responsiveness for the evolution of regional house prices in response to demand shocks or the ability of different regions to accommodate population and economic growth.

Grimes and Aitken (2010) and Paciorek (2013) previously investigated the first question, finding that regions with lower supply responsiveness tend to experience larger house price increases in response to demand shocks. In these regions, an inability to produce housing at a sufficient rate contributes to scarcity-driven price inflation. My analysis could therefore be extended to better understand the impact of regulatory delay and geographic constraints on developable land on house price dynamics in New Zealand.

⁷ A more subtle issue is that some city councils occasionally adjust their boundaries in order to access more developable land.

There is an emerging literature on the impact of housing supply constraints on regional population growth. In the US, Saks (2008), Hsieh and Moretti (2015), Ganong and Shoag (2017) and Glaeser and Gyourko (2017) have found evidence that supply constraints in California and the Northeast have significantly distorted population location decisions. In the Netherlands, Vermuelen and van Ommeren (2009) and de Groot *et al* (2015) suggest that spatial planning policy has reduced the size of major cities in the Randstad (the main urban conglomeration) relative to what would have otherwise occurred.

Given my findings about variations in housing supply responsiveness between New Zealand regions, further research is needed to understand whether restrictive land use regulations and/or geographic constraints are distorting the location of population or economic growth in New Zealand.

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8. Technical appendix

8.1. Descriptive statistics for model variables

The following table provides descriptive statistics for the variables used in the model for the observations in the trimmed dataset. A few things worth highlighting in the data are as follows:

- Quarterly consents and dwelling stock vary considerably between regions, but there is less variation in consents per dwelling stock
- There is more variation in house prices and land costs than in construction costs.
- On average, house prices are only slightly higher than construction costs, but there are cases where house prices are significantly higher or lower than construction costs. Similarly, construction costs are higher than land costs for the average observation, but there are cases where the opposite is true.
- There is significant variation in the variable for developable land – at the extremes, almost 100% of the land in Hamilton is available for development, while only 8.8% of the land in Queenstown is developable.
- There is also significant variation in regulatory delay – Stratford and Otorohanga processed all consents within statutory timeframes, while 53% of consents in Kaikoura were delayed beyond statutory timeframes.

Table 7: Descriptive statistics for model variables

Variable	Mean	Std dev	Min	Max
<i>Measures of housing supply</i>				
HC _{i,t}	76.8	254.7	0.0	4,113.0
H _{i,t}	19,800.5	52,742.7	1,066.0	469,986.0
<i>Measures of house prices and costs</i>				
HP _{i,t}	\$248,329	\$105,529	\$51,071	\$809,934
LV _{i,t}	\$123,238	\$73,741	\$10,822	\$651,451
CC _{i,t}	\$232,615	\$65,034	\$52,074	\$616,661
<i>Geography and regulatory delay variables</i>				
DL _i (as share of total land)	0.516	0.270	0.089	0.998
B _{i,t}	0.0099	0.0223	0.0001	0.1411
T _i	0.188	0.138	0.000	0.528
<i>Instruments for house prices</i>				
Bartik _{i,t}	0.0158	0.0157	-0.0568	0.0613
Migration _{i,t}	0.0019	0.0011	0.0004	0.0098
Income _{i,t}	9.277	0.165	8.920	9.585
<i>Transformed model variables</i>				
HC _{i,t} / H _{i,t}	0.0037	0.0030	0.0000	0.0622
ln (HP _{i,t} / CC _{i,t})	0.0069	0.3655	-1.1633	1.3676
ln (CC _{i,t} / LV _{i,t})	0.7709	0.5153	-0.6415	2.4042

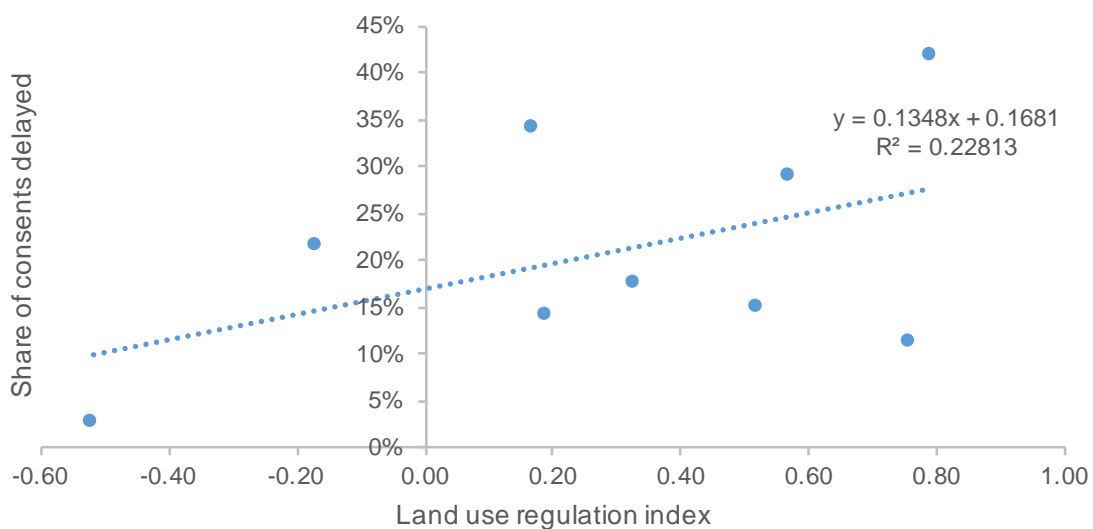
8.2. Validity of regulatory delay measure

In order to understand whether my regulatory delay measure reflects persistent features of local regulatory practice and/or policy, I compare it with two recent attempts to measure the restrictiveness of planning regulations. This is especially important given the fact that RMA reforms implemented since 2006 have tightened requirements for councils to process consents within statutory timeframes. Since then, the share of consents processed within timeframes has risen at almost all councils.⁸

⁸ However, statutory timeframes can be extended under some situations, eg if councils request additional information from applicants. As a result, the average number of working

The following chart compares the regulatory delay measure with a land use regulation index that NZIER (2015) developed for nine TLAs, following a similar US index. There is a positive correlation between the two measures, indicating that TLAs where more consents were delayed in the early 2000s tended to have more restrictive land use regulations in the mid-2010s. There was also a positive correlation between my consenting delay measure and NZIER's delay sub-index, albeit with a lower R².

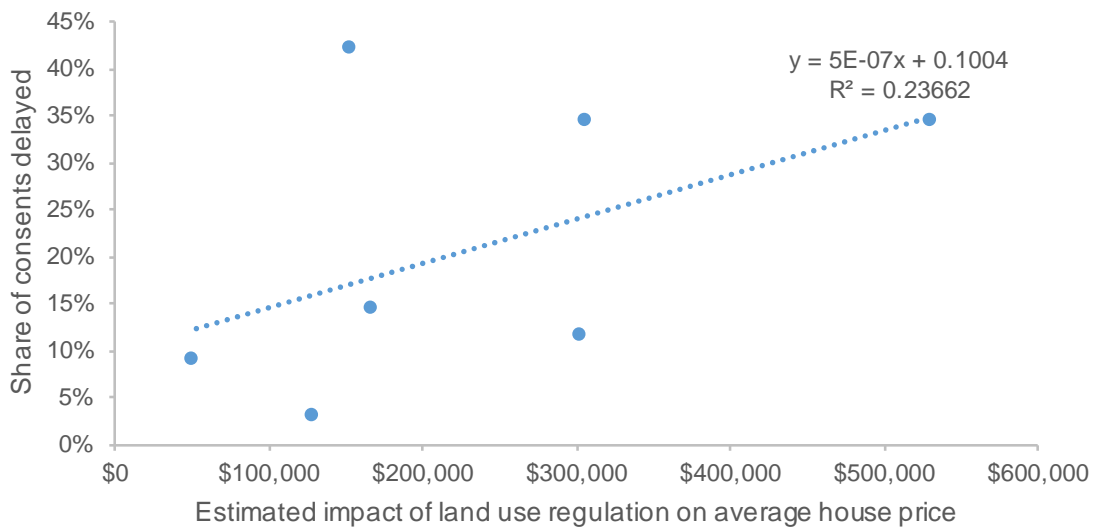
Figure 3: Correlation between NZIER (2015) land use regulation index and regulatory delay measure



The following figure shows the correlation between the regulatory delay measure and a recent estimate of the impact of land use regulations on the price of an average home in seven urban TLAs (Sense Partners, 2017). Once again, there is a positive correlation between these measures, indicating that cities that had higher regulatory delay in the early 2000s tended to have more distorted house prices in the mid-2010s.

days required to process consents still varies considerably. This is not recorded in a consistent way in the MfE data and hence I am unable to use this information.

Figure 4: Correlation between Sense Partners (2017) estimate of the impact of land use regulation on house prices and regulatory delay measure



These comparisons suggest that the regulatory delay measure that I have constructed using MfE data reflects persistent differences in TLAs' approach to processing resource consents and/or the overall restrictiveness of their land use regulations.

8.3. Is regulatory delay exogenous?

An important finding in Saiz (2010) is that tighter geographic constraints are positively correlated with more restrictive land use regulations. Saiz interprets this as evidence in favour of William Fischel's 'homevoter hypothesis' – ie geographic constraints lead to higher home prices, which in turn encourage local voters to demand tighter planning controls to protect the value of their homes. (See Fischel, 2015 for further discussion.) He therefore instruments for the stringency of land use regulation in his analysis.

If land use planning policies and/or processes are also endogenous in New Zealand, it may invalidate my inference around the effect of regulatory delay on housing supply responsiveness. Consequently, I investigate whether there is a positive correlation between

regulatory delay and geographic constraints. If so, it may suggest that the regulation measure is endogenous and hence that it requires a different estimation approach.

The following chart shows the correlation between my regulatory delay measure and the share of land in each TLA that isn't steeply sloping. Contra Saiz, there is a weak *negative* correlation between these measures ($R^2 = 0.046$), albeit not one that is statistically significant even at the 10% level. Similarly, regulatory delay is uncorrelated with annual average sunshine hours (SNZ, 2017d), which is another exogenous geographical factor that may lead to higher house prices or growth rates.

This suggests that regulatory practices are likely to be exogenous to house price changes in New Zealand. This may reflect countervailing forces that offset 'homevoter' dynamics. For instance, higher house prices may encourage some local governments to improve the efficiency of land use regulatory policies or practices, rather than tightening them. This is supported by the experience of the Auckland Unitary Plan, where planning rules were significantly loosened in response to evidence that housing supply constraints were raising prices.

Figure 5: Correlation between regulatory delay measure and constraints on developable land

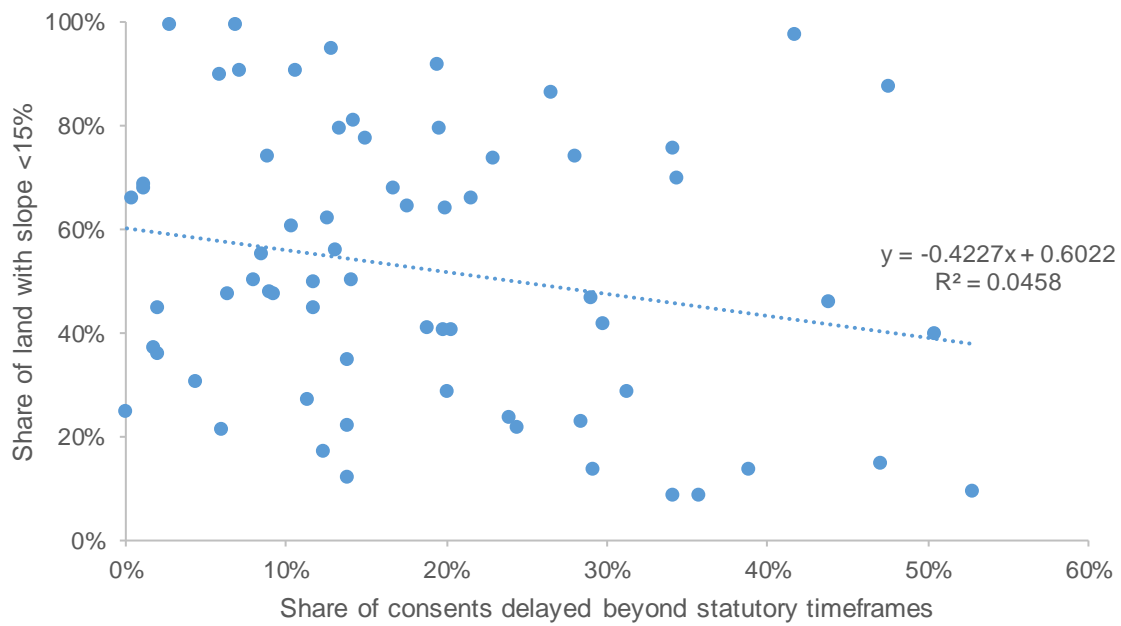
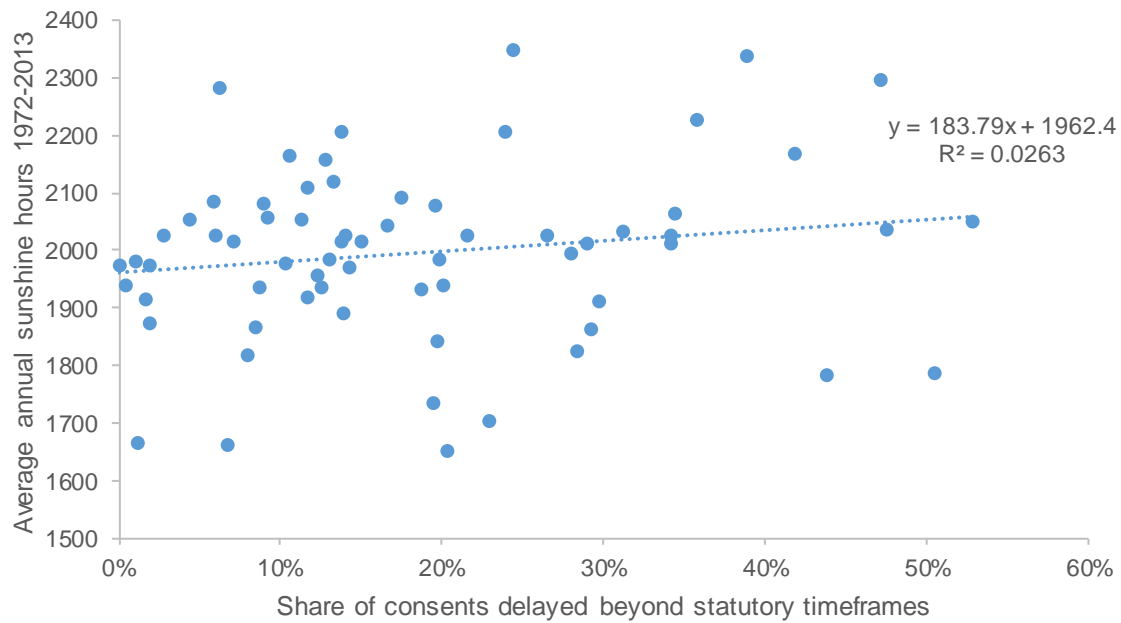


Figure 6: Correlation between regulatory delay measure and average annual sunshine hours



8.4. Calculation of Bartik labour demand shock

I calculate the labour demand shock as follows:

Equation 2: Calculation of labour demand shock

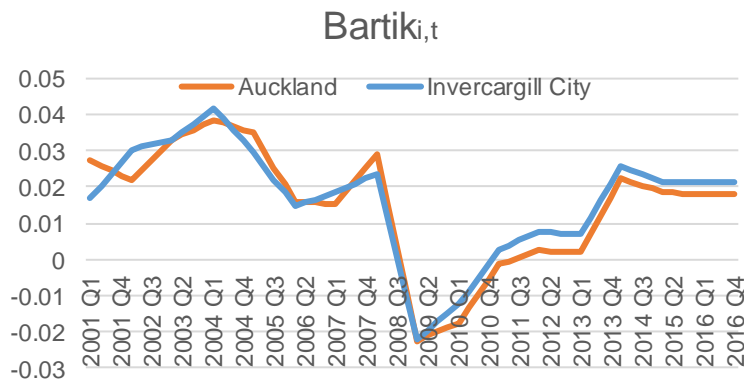
$$Bartik_{i,t} = \sum_k \left(\frac{E_{i,t-1,k}}{\sum_m E_{i,t-1,m}} \right) * \left(\frac{\sum_{j \neq i} E_{j,t,k}}{\sum_{j \neq i} E_{j,t-1,k}} - 1 \right)$$

where $E_{i,t,k}$ is employment in industry k in TLA i at time t . The first term in this equation calculates industry k 's lagged employment share in TLA i , while the second term calculates the percentage change in employment in industry k in all other TLAs. Multiplying these together and summing up across all industries provides a measure of the degree to which labour demand in TLA i would increase if it was affected by the same industry-level trends as the rest of the country. I exclude the construction industry (ANZSIC06 industry C) to avoid potential endogeneity with housing supply, as positive (negative) shocks to demand for construction workers may increase (reduce) construction costs.

As noted, the source data for this is SNZ's Business Demography Statistics, which are published at the TLA and 2-digit ANZSIC06 industry level on an annual basis. I therefore calculate this measure on an annual basis (using data published for quarter 1 of each year) and linearly interpolate to a quarterly basis.

The following diagram shows this measure for Auckland and Invercargill. This shows that both TLAs have experienced similar labour demand shocks over the period, possibly due to macroeconomic factors affecting many industries in the early 2000s and following the GFC. A broadly similar pattern is observed in many TLAs, although with more variation in smaller rural TLAs than between urban TLAs.

Figure 7: Bartik labour demand instrument for Auckland and Invercargill



8.5. Calculation of inward migration shock

I calculate the inward migration shock variable using an analogous approach:

Equation 3: Calculation of labour demand shock

$$Migration_{i,t} = \sum_k \left(\frac{P_{i,t-1,k}}{\sum_m P_{i,t-1,m}} \right) * \left(\frac{\sum_{j \neq i} M_{j,t,k}}{\sum_{j \neq i} P_{j,t-1,k}} - 1 \right)$$

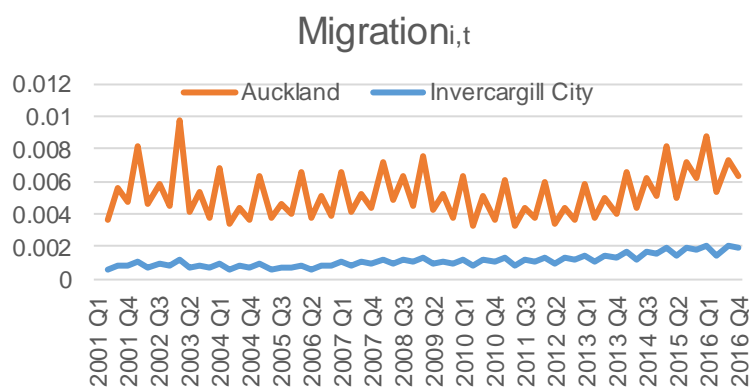
where $P_{i,t,k}$ is the population born in country k in TLA i at time t , and $M_{i,t,k}$ is the number of non-New Zealand citizen permanent and long-term migrants who are arriving from country k at time t and who report that they are intending to settle in TLA i .⁹ The first term in this equation calculates country k 's lagged share of the population of TLA i , while the second term calculates the gross percentage change in the population of migrants from country k in all other TLAs. Multiplying these together and summing up across all countries of origin provides a measure of the degree to which population in TLA i would increase if it was affected by the same migrant arrival trends as the rest of the country.

⁹ Throughout this time period, around 10% of migrant arrivals did not report a TLA destination. This share is stable over time and hence I have excluded migrants who do not report a destination location within New Zealand.

I estimated this measure using a custom data request for SNZ’s International Travel and Migration Statistics, as well as data from the 2001, 2006, and 2013 Censuses.¹⁰ This data request provided information on PLT migrant arrivals and departures at a quarterly level, broken down by TLA destination / origin within New Zealand, whether or not the migrant was a New Zealand citizen, and where they were originating or departing to.¹¹ I have discarded data on migrant departures, as these may be affected by local factors within New Zealand (eg difficulty finding housing or employment) and hence are less likely to be exogenous. I have also discarded data on arrivals of New Zealand citizens, as these are less likely to follow conventional chain migration patterns.

The following diagram shows this measure for Auckland and Invercargill. This shows that both TLAs have experienced variations in migration shocks over this period, and also that Auckland has a significantly higher average level on this measure, which accords with intuitions about the role that migration plays in growth in both cities.

Figure 8: Migration instrument for Auckland and Invercargill



¹⁰ I linearly interpolated the share of population born in different countries between Census years.

¹¹ Country of origin / destination included the 19 main sources of migrants (Australia, Canada, China, Fiji, France, Germany, Hong Kong, India, Ireland, Japan, South Korea, Malaysia, Philippines, Samoa, Singapore, South Africa, Thailand, United Kingdom, and United States) plus five categories for migrants from other countries in Asia, North/South America, Europe, Oceania, and Africa / Middle East.

8.6. Calculation of income shock

I calculate the income shock using an analogous approach to the Bartik instrument:

Equation 4: Calculation of income shock

$$Income_{i,t} = \ln \left[\sum_k \left(\frac{E_{i,t,k}}{\sum_m E_{i,t,m}} \right) * \left(\frac{\sum_{j \neq i} N_{j,t,k}}{\sum_{j \neq i} E_{j,t,k}} \right) \right]$$

where $E_{i,t,k}$ is employment in industry k in region i at time t and $N_{j,t,k}$ is total income earned in industry k in region j at time t . The first term in this equation calculates industry k 's employment share in region i , while the second term calculates the average per-worker income in industry k in all other region. Multiplying these together and summing up across all industries provides a measure of what the level of average per-worker income in region i would be if it was affected by the same industry-level trends as the rest of the country. I exclude the construction industry (ANZSIC06 industry C) to avoid potential endogeneity with housing supply, as positive (negative) shocks to demand for construction workers may increase (reduce) construction costs. Finally, I log-transform the variable.

As noted, the source data for this is SNZ's Linked Employee-Employer Database, which are published at the regional council and 1-digit ANZSIC06 industry level on a quarterly basis. In effect, this dataset provides higher-frequency data on employment and incomes than the Business Demography Statistics used to calculate $Bartik_{i,t}$, but with less granularity at the industry and geographical level.

The following diagram shows this measure for Auckland and Invercargill. This shows that both TLAs have experienced similar income shocks over the period, possibly due to macroeconomic factors affecting many industries in the early 2000s and following the GFC. A broadly similar pattern is observed in many TLAs.

Figure 9: Income instrument for Auckland and Invercargill

