A New Zealand Regional Housing Model

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Abstract
The New Zealand Regional Housing Model (NZRHM) includes estimated equations for four key housing market variables: house prices, housing supply (new dwelling consents), residential vacant land (lot) prices, and average rents. Long run (cointegration) relationships and short run (error correction) relationships are estimated for each of these variables across 72 TLAs within New Zealand. The model is designed so that it can be used for short to medium term forecasting. It is also useful for simulating the effects of shocks to the housing market. The paper presents simulations of the impacts of shocks to exogenous variables (population, credit restrictions, construction costs and farm prices) as well as shocks to policy variables (developer contributions, accommodation supplement, and land availability). We also simulate the consequences of the Christchurch earthquakes for Canterbury housing outcomes. The over-arching conclusion across all simulations is that housing markets are very slow to adjust to disequilibria, such that exogenous shocks have very long lasting effects on prices and the housing stock.

JEL codes
R21, R31

Keywords
House prices, housing supply, lot prices, rents, housing model

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Executive Summary

The New Zealand Regional Housing Model (NZRHM) provides a framework to analyse the impacts of key policy choices (e.g. changes in development contributions or land supply) and other exogenous influences (e.g. population changes) on housing market outcomes. It can also be used for short to medium term forecasting purposes.

Four key variables are modelled: house prices, housing supply (new dwelling consents), residential vacant land (lot) prices, and average rents. Each of these is modelled at the TLA level across 72 TLAs within New Zealand. Equations are estimated using quarterly data from the early to mid 1990s to 2011Q2.

The four modelled (endogenous) variables interact with each other and are influenced by a range of exogenous influences. Thus one can trace the effects of, say, a change in the rate of development contributions through to residential lot prices, house prices, rents and new housing supply.

Each of the four modelled relationships has a long term (equilibrium) component that shows the value to which the modelled variable will tend given the values of the policy and exogenous variables in the system. The values of the policy and exogenous variables will alter over time, so the equilibrium path of each modelled variable will also change over time. Values of the exogenous variables differ across TLAs and so each TLA – while driven by the same underlying economic forces – will have differing housing market outcomes reflecting its own population and other developments.

In addition, the model is estimated with a dynamic component that shows how each endogenous variable moves on a quarterly basis towards the equilibrium. In doing so, recent changes in other variables may impact the dynamic adjustment path, potentially causing some initial movements away from equilibrium. Price expectations, in particular, may cause housing market adjustments that lead to temporary deviations in outcomes away from equilibrium.

Figure 1, in the main body of the paper, provides a schematic demonstration of the inter-relationships within the model. These relationships are briefly summarised as follows.

House prices in each TLA are determined, in the long run, positively by: population relative to the existing housing stock, the level of accommodation supplement payable to homeowners, and long term income developments (represented by a trend term). House prices are influenced negatively by the cost and the restrictiveness of credit. Additional short term influences include changes in regional economic activity and changes in average rents (both positively).

In the long run, lot prices (i.e. prices for residential vacant land) are positively determined, by: farm prices, house prices, development plus financial contributions that are payable to the council, and by population pressures (current population relative to population in 1991).

Long run rents are positively determined by: house prices and interest rates (the one year mortgage rate). Rents are influenced negatively by expectations of future house price inflation (proxied by three year rates of past house price inflation) since expected capital gain forms part of the total expected return on a rental property for a landlord. An additional (positive) short term influence is the change in the average rate of accommodation supplement payable to renters.

An equilibrium relationship exists between house prices and the total cost of building a new dwelling comprising both lot prices and construction costs. New dwelling supply (proxied by new housing consents) reacts positively to: the ratio of house prices to total new dwelling costs, and rates of change (over the preceding three years) in house prices and construction costs. New dwelling supply reacts negatively to changes in the restrictiveness of credit.

The value of the model is illustrated by simulating the implications of various shocks to the model for the Manukau TLA, including shocks to exogenous variables (population, credit restrictions, construction costs and farm prices) as well as to policy variables (developer contributions per housing consent, accommodation supplement receipts and land availability). We further test the model by replicating several key consequences of the Christchurch Earthquakes, and consider the dynamic effect on the housing markets of Christchurch City and the surrounding TLA's.

The over-arching conclusion across all simulations is that housing markets are very slow to adjust to disequilibria, such that exogenous shocks have very long lasting effects. Specifically, we find that an increase in population leads to a prolonged period of upward pressure on prices (house, land and rent), continuing until the dwelling stock adjusts to restore dwellings per capita. The model shows that tighter credit restrictions lead to a large subsequent reduction in housing construction and prices; however the lower level of construction leads to a lower stock of housing which introduces upward pressure on prices due to the fixed population. This, in turn, ultimately encourages local construction and prices to move back towards baseline in spite of permanent changes to credit restrictions, with a permanently lower dwelling stock as the result.

In further simulations, the NZRHM suggests a productivity increase that reduces national construction costs will lead to a higher stock of dwellings for an extended period, and a permanently lower level of house (and land) prices. Increasing farm prices or developer contributions per housing consent affects the price floor for residential vacant land. However, we estimate only a small effect on Manukau land prices as a result, since these prices are determined more by demand side factors (house prices less construction costs) than by supply side factors. We therefore estimate only very small impacts on house prices or construction activity. Greater accommodation supplement receipts lead to increased house, land and rental prices, which drive greater construction. Finally, we find that increasing land availability leads to lower land prices, but this change is insufficient to have a material effect on other outcomes over the relatively short 5-year window that is simulated.

In response to our Christchurch Earthquake simulations, the NZRHM suggests that Waimakariri and Selwyn will experience a shortage of housing for an extended period, which will be reflected in house and land prices following the housing stock and population changes after the Christchurch earthquakes. The key implications for Christchurch City are that the destruction of housing and land will lead to a significant and prolonged degree of upward pressure on prices and construction. However if population adjusts to a lower level in the long run, prices should return to the baseline comparison, with a permanently lower stock of housing thereafter.

1. Introduction

The New Zealand Productivity Commission (2012) report into housing affordability highlighted a number of important policy questions. These questions include: How does a change in land availability affect land prices, house prices, rents and new construction? How does a change in construction costs affect these outcomes? How does migration affect these outcomes? Currently, there is no model available in New Zealand that can answer these questions at a regional or even a national scale.

The New Zealand Regional Housing Model (NZRHM) has been built to provide answers to these questions. It does so at the Territorial Local Authority (TLA) level, and so is able to address housing issues that are specific to particular cities, towns and rural areas. The data covers the 72 TLAs that existed prior to Auckland's amalgamation, and continues to treat Auckland as seven separate areas.

Four key variables are modelled: house prices, housing supply (new dwelling consents), residential vacant land (lot) prices, and average rents. Each of these is modelled at the TLA level. Equations are estimated using quarterly data from the early to mid 1990s to 2011Q2 (starting dates depend on data availability). The model can be used for analytical purposes (e.g. to model effects of a change in accommodation supplement or in migration) and for short to medium term forecasting purposes.

While drawing on prior models estimated within New Zealand (especially Grimes and Aitken, 2007 and 2010), this model uses superior data that was unavailable for previously published models, especially for the price and cost variables. The data sources have been chosen so that they are readily updateable in future. In obtaining the data, considerable work has had to be undertaken to derive new quarterly series, at the TLA level, on a range of variables including: the number of dwellings, residential land (lot) prices, and average development plus financial contributions for new developments.

The next section provides a broad overview of the model. Data and estimation issues are then discussed briefly (with fuller discussion of data in the Data Appendix). Detailed descriptions of the four key relationships – house prices, housing supply, lot prices, and rents – are then presented. In each case, the estimation approach provides both long run equilibrium relationships amongst the variables, and short run equations describing the dynamic adjustment of each variable over time towards the long run equilibrium. Exogenous variables which affect the long run equilibrium (e.g. population and incomes) change over time, so the long run equilibrium outcome for each endogenous variable also changes over time. Simulations of the full model in response to various shocks are then presented, with the paper concluding with some suggested possibilities for further developments.

2. Model Overview

The New Zealand Regional Housing Model comprises four key relationships explaining: house prices, house construction (and hence dwelling stock), residential land (lot) prices, and rents. The model is estimated across all 72 Territorial Local Authorities (TLAs) in mainland New Zealand (keeping the newly amalgamated Auckland TLAs as separate authorities, and incorporating the former Banks Peninsula TLA as part of Christchurch City). All modelling uses quarterly data extending from the early to mid 1990s to 2011Q2.

For modelling purposes, a single aggregate housing market is assumed to exist within each TLA; thus we do not differentiate between housing of different quality within a TLA. The same housing market relationships (e.g. functional form and elasticities) are assumed to operate across all TLAs. However, specific features of individual TLAs are included in the model through inclusion of TLA-specific values for exogenous influences (e.g. population) and through inclusion of TLA fixed effects, whilst we also test for the equality of a set of responses across sub-groups of TLAs.

The model can be used both for policy simulation purposes and for short to medium term forecasting. Data sources have been chosen to be capable of easy updating so that the model can be kept current and be used for forecasting purposes. The requirement that data be capable of easy updating is a key reason behind the assumption of a homogeneous housing market within each TLA. This requirement – along with availability of data at TLA level – also affects the choice of variables included in the model specification.

Two of the four key relationships are based on the model published by Grimes and Aitken (2010), specifically a supply equation for new houses and a demand equation. The demand equation takes the supply of houses (dwellings) as given in the short run and therefore takes the form of a house price equation.

The third relationship is an equation determining residential lot (vacant section) prices. This relationship is included both because of its intrinsic interest (i.e. why are residential lot prices high or low in some areas, and do policy choices affect lot prices) and because lot prices themselves influence the supply of new dwellings (and hence long run house prices).

The fourth relationship is an equation determining average rents. The level of rents is of policy interest in its own right. Furthermore, some policies that could affect rents (e.g.

accommodation supplement receipts) may also affect house prices, so there are policy as well as economic modelling reasons for treating rents and house prices as an inter-related system.

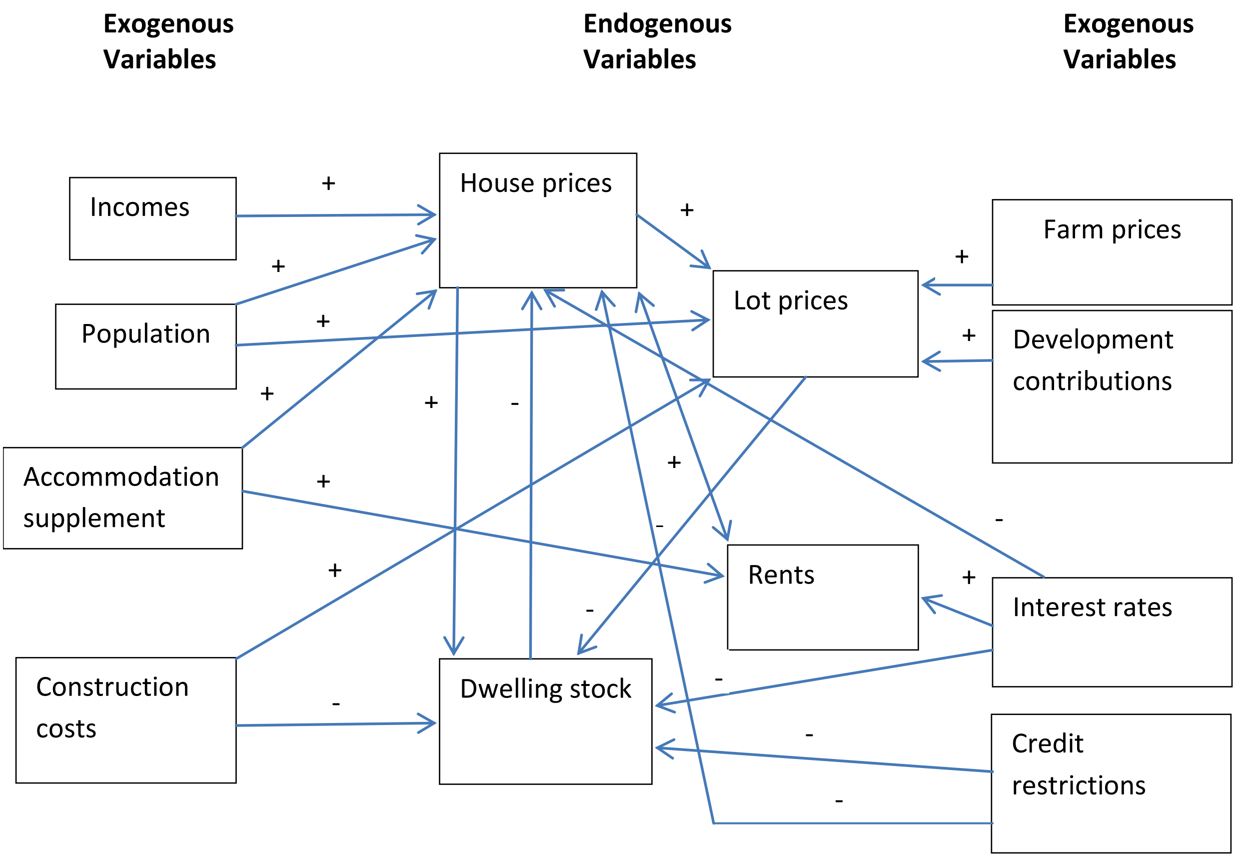
Other variables are left unmodelled, i.e. are treated as exogenous to this system of equations. These variables, which have important roles in influencing housing outcomes, include: population, building construction costs (at national level), incomes, interest rates, and housing-related policy variables (e.g. development contributions and accommodation supplement). Some of these variables, such as population, could in future be modelled so as to include their interrelationships with housing influences.

The equations are modelled using panel cointegration and error correction approaches, given the time series properties of the data. This approach enables us to identify long run equilibrium relationships between variables and to model the dynamics of adjustment towards the long run equilibrium following shocks to the system.

The recursive nature of the model enables us to simulate the effects of an individual shock as it feeds through to multiple variables in the model over time (taking the values of exogenous variables as given). For instance, the model can simulate the impact of a rise in developer contributions on residential lot prices, thence to new housing supply, house prices and rents. In doing so, population and incomes of an area are assumed to remain unaffected; thus the simulation is best thought of as a short to medium term analysis that does not (at this stage) incorporate population and non-housing economic responses.

Figure 1 provides a schematic representation of the model. The four endogenous variables (house prices, dwelling stock, lot prices and rents) are affected by a range of exogenous factors. In addition, endogenous variables interact amongst themselves. Key aspects of the model are explained below.

Figure 1: Schematic Representation of Housing Model



House prices, in the long run, are determined by the demand for housing relative to the existing supply of dwellings. The latter is pre-determined in the short-run by the stock of houses at the end of last quarter (with new supply being unable to react to new information within a quarter). The specification of housing demand (and hence house prices) is based on a model of optimising consumers. Housing demand is affected positively by rises in population (relative to the dwelling stock), incomes and governmental support for owner-occupiers; rents also affect house prices positively in the short run. House prices are affected negatively by interest rates (less expectations of house price inflation), bank credit restrictions (reflected, for instance, through higher owner equity requirements), and the dwelling stock.

Additions to the dwelling stock occur when it is profitable for builders/developers to build new dwellings. Thus new construction responds positively to increasing house prices, but is affected negatively by rises in residential lot prices and construction costs. New construction is also restricted by tighter credit conditions.

The lower bound on residential lot prices is determined by farm prices plus development contributions (that must be paid to the local council when developing the land) plus construction costs incurred in developing farmland into residential lots. However, lot prices may rise above this base level according to the level of local house prices and the impact of population pressures (for example, because of the presence of zoning or geographical constraints on expansion).

Rents are set so as to provide landlords with a market yield, given the level of house prices. Thus rents rise in response to increases in both house prices and interest rates. The total real yield to landlords equals the rental yield plus expected real capital gains on the house; thus rental yields fall as expected capital gains rise. Rents (relative to house prices) may also rise as government rental assistance (accommodation supplement) rises. The effect of this policy instrument will depend on the elasticity of supply of new landlords and so will differ in the long run relative to the short run given that this elasticity is likely to increase as the time horizon lengthens.

Each of the four relationships is described in more detail below. First, the data and data sources are described, and the estimation methodology is outlined.

3. Data

Most of our data series are available (or proxied) for the 72 TLAs that existed prior to Auckland's amalgamation. The seven Auckland TLAs continue to be treated as separate entities in the model. Some series are available only nationally (indicated by the lack of an 'i' subscript for the variable). All data are available or converted to quarterly frequency, and most are available from the time of TLA formation in 1991 through to 2011 (though some series are available only for shorter timespans).

Appendix 1 provides a detailed description of every data series; the source data is described in section A, and any processes used to convert it into its final form is explained in section B. A briefer description of the raw series used in our modelling, and their sources, is provided in Table 1. The data frequency in this table refers to the frequency of the source data; where this is not listed as being quarterly, we have constructed quarterly proxies as described in the data appendix.[1]

[1] We note that generated data in this manner leads to greater standard errors than indicated by standard regression software outputs (i.e. a generated regressor problem). In practice, virtually all macro data (even official CPI or GDP series) are generated data and so suffer from the same issues; hence standard errors are likely to be uderstated when running regressions using (implicitly or explicitly generated) macro data.

This model makes use of long-run relationships and short-run deviations about this relationship. The long run equations establish relationships between (non-stationary) variables that have a changing mean over time, while the short run equations establish relationships between (stationary) variables that have a constant mean over time. As a result, it is important to consider the order of integration for each series that appears within the model (i.e. to test whether the variables have a constant or changing mean over time). For national series, we test for stationarity in both levels and changes of the series using an Augmented Dickey-Fuller (ADF) test, where the lag length is chosen to minimise the Schwarz Bayesian Information Criterion (SBIC). For regional series we test for a unit root in both the level and changes of the series with the Im-Pesaran-Shin (IPS) panel unit root test. Under both tests the null hypothesis is that the series has a unit root (changing mean over time). Table 2 presents the results of these tests for all variables used in our final estimates, where the first column states which test is used, depending on whether the series is regionally varying, whilst the second and third columns display the p-value from the test under the null hypothesis of a unit root in levels and changes, respectively.

Table 1: Data Definitions – Raw Series

Variable	Definition	Source	Data Frequency
AS^*	Accommodation Supplement (multiple series):	MSD	Quarterly
CR	Credit restrictions	RBNZ	Quarterly
DC_i	Development contributions	DBH & SNZ	Quarterly
H_i	Censal Dwelling stock	SNZ	5 yearly
HC_i	Housing consents	QVNZ	Quarterly
i^m	1 year mortgage interest rate	RBNZ	Quarterly
N_i	Population	SNZ	Annual
PB	Residential construction cost	SNZ	Quarterly
CPI	Consumer price index	SNZ	Quarterly
PF_i	Farm price	QVNZ	Quarterly
PH_i	House price	QVNZ	Quarterly
PL_i	Lot price	QVNZ	Quarterly
R_i	Average rental	DBH	Quarterly
REA_i	Regional economic activity	ANZ/NBNZ	Quarterly
$Time$	Time trend	n/a	Quarterly

ANZ/NBNZ=ANZ/National Bank of New Zealand; DBH=Department of Building and Housing (now MBIE); MSD=Ministry of Social Development; QVNZ=Quotable Value New Zealand; SNZ=Statistics New Zealand; RBNZ=Reserve Bank of New Zealand.

Table 2: Data Summary – Utilised Series

Variable	Test	H0: Unit Root in Levels	H0: Unit Root in Changes
AS^{O-Real}	ADF	[0.2887]	[0.0000]
AS^{R-Rate}	ADF	[0.2836]	[0.0000]
CR	ADF	[0.6670]	[0.0062]
DC_HC_i	IPS	[0.9080]	[0.0000]
H_i	IPS	[1.0000]	[0.0000]
H_i/N_i	IPS	[1.0000]	[0.0000]
HC_LH_i	IPS	[0.0000]	[0.0000]
i^m	ADF	[0.0556]	[0.0000]
N_i	IPS	[1.0000]	[0.0000]
PB	ADF	[0.9522]	[0.0446]
PB^G	ADF	[0.0996]	[0.1674]
PC	ADF	[1.0000]	[0.0000]
PF_i	IPS	[0.0000]	[0.0000]
PH_i	IPS	[1.0000]	[0.0000]
PH_i^G	IPS	[0.9970]	[0.0000]
$PH_{i,t-1} \times AS_{t-1}^{R-Rate}$	IPS	[1.0000]	[0.0000]
$PH_{i,t-1} \times PH_{i,t-1}^G$	IPS	[0.6972]	[0.0000]
PL_i	IPS	[1.0000]	[0.0000]
PL_i^G	IPS	[0.0470]	[0.0000]
R_i	IPS	[1.0000]	[0.0000]
$R/L.PH_i$	IPS	[0.5964]	[0.0000]
REA_i	IPS	[1.0000]	[0.0000]
UC_i	IPS	[0.6850]	[0.0000]

The stationarity of the series follows general perceptions. The housing investment rate, defined as the number of new housing consents relative to the existing housing stock, exhibits strong evidence of stationarity. (Farm prices, unexpectedly, also appear stationary in levels although this may be due to noise in the series that can bias the test towards rejecting a unit root, and we treat them as being non-stationary.) There is weak evidence of stationarity in interest rates, as well as the average growth rate in building costs and lot prices; in these cases it is best to treat the series as being non-stationary in levels. We fail to reject the null hypothesis of nonstationarity for all other level series. For every series except building costs, as well as its geometric average growth rate, we reject the null hypothesis of a unit root in changes at the 1% significance level. We can reject the null hypothesis of a unit root in changes of building costs at the 5% significance level. The test statistic on the level of building cost average growth has a p-value of less than 0.10, so we treat the change in this variable as being stationary, although the test statistic on the differenced variable possibly indicates a degree of "over-differencing".

4. Methodology

We adopt a panel estimation framework to model each of our relationships using a cointegration-based approach. Using this approach, a long run equilibrium (cointegrating) relationship is estimated. The estimated residual from this equation must be stationary; i.e. have a mean of zero consistently over the full sample. Accordingly, over time, the values of the variables included in the equation return to the estimated relationship amongst themselves, thus implying a long run relationship between these variables.

This long run equilibrium equation is supplemented by a short run (error correction) equation. The latter equation tests whether changes in the variable of interest respond significantly to the lagged disequilibrium term (i.e. to the lagged residual from the cointegrating equation). A significant response to the lagged disequilibrium term is required to establish that the variable of interest does adjust towards equilibrium following a shock. The error correction equations also include other (stationary) variables to model the dynamics of adjustment. All variables in the error correction equations are lagged to avoid endogeneity (simulataneous determination) problems.[2]

We use the same panel unit root test (IPS) as used in the data section to test for stationarity (versus the null hypothesis of a unit root) of the residual from the long run equation. We also employ the Levin-Lin-Chu (LLC) panel unit root test, although this test assumes that the same time series processes operate across TLAs whereas the IPS does not make this restriction. For this reason, the IPS is our preferred test. However we note that neither the IPS nor the LLC test is strictly appropriate to test the stationarity of a residual obtained using estimated parameters. We therefore supplement these tests with the requirement that the residual from the cointegrating regression be strongly significant ($p<0.01$) in the error correction equation.

[2] Endogeneity is not an issue in the cointegrating regressions given the super-consistency property of coefficients on non-stationary variables in such regressions. .

The cointegrating equations all include area (TLA) fixed effects, which allow for a different constant term for each TLA reflecting (unchanging) local conditions. Three of the four equations also include time fixed effects reflecting national developments. For the house price equation we consider that there may be unobserved trending factors applicable to housing demand in specific TLA's (e.g. a changing preference towards certain amenities within that TLA) and so we include TLA-specific time trends to reflect these factors. The short run equations do not include separate area or time fixed effects (or time trends) given that these are incorporated into the long run relationships. No spatial interactions between TLAs have been incorporated. Future work could examine issues of spatial interactions, especially within larger conurbations.

All equations are estimated initially by ordinary least squares (OLS). This is appropriate for the long run (cointegration) equations (given their super-consistency properties with non-stationary variables). It is also appropriate (although not necessarily efficient) for the short run (error correction) equations given that no current endogenous variables are included in these equations.

For each of the short run equations we present a table of estimates for the preferred specification. The first column in each of these tables presents OLS estimates with conventionally-estimated standard errors. The adjusted coefficient of variation ($\overline{R^2}$) and F-statistic for the model (with associated significance value) are presented. The φ coefficient is the (Prais-Winston) estimate of the autoregressive parameter in the residuals to indicate the degree of residual autocorrelation in the estimated equation. The second column presents the OLS estimates with Newey-West standard errors that are robust to the presence of autocorrelation and heteroskedasticity. (Coefficient estimates are identical to those in the first column so other test statistics are not repeated.) A heuristic test of the equation's specification is to examine whether the Newey-West standard errors are similar to the conventional OLS standard errors; if they are, then the OLS specification is broadly free of heteroskedasticity and autocorrelation. The third column presents estimates obtained when we estimate all four short run equations (for house prices, house supply, lot prices and rents) together as a system using seemingly unrelated regressions (SUR). In this case, the number of observations is given by the equation with the shortest time span for data (1997Q3-2011Q2). These estimates take account of the information in all four equations when estimated as a system, and so are more efficient than the single equation estimates. The SUR results (which are very similar to the OLS results) represent our preferred short run model estimates.

The following four sections describe each relationship in more detail. For a less technical description of each relationship, refer to the Executive Summary.

5. Model Estimates

5.1. House Prices

House prices are a jump variable, equating short run housing demand with fixed short run supply. Accordingly, house prices can be modelled using an inverse demand function, taking supply as given in the short run. Demand for housing services is one element in a system of consumer demands and can therefore be modelled using a standard intertemporal consumption capital asset pricing model (Merton, 1973). If we assume that consumers have constant relative risk aversion utility functions that are separable in each period between non-housing consumption and housing services, the aggregate equilibrium inverse demand function is given by (Pain and Westaway, 1997; Grimes and Aitken, 2010):

$$\ln\left(\frac{PH_{it}}{PC_t}\right) = (1-\delta)\ln\theta - \delta\ln\left(\frac{H_{it}}{N_{it}}\right) + \delta\ln\left(\frac{Cons_{it}}{N_{it}}\right) - \ln UC_{it} \tag{1}$$

where δ is the coefficient of relative risk aversion and θ is the ratio of housing services to the housing stock. Derivation of this equation is reproduced in Appendix 2.

The real house price (PH/PC) is decreasing in the per capita housing stock (H/N) and the real user cost of capital (UC), whilst increasing in real consumption $(Cons)$ per capita, where *N* is population. The real user cost of capital is defined as the real opportunity cost of investment, less three year extrapolated real growth in house prices; the specification is detailed in the Data Appendix, subsection B.8. The extrapolated real house price growth variable (which is specified as in Grimes and Aitken (2010) to avoid "data mining"), reflects a maintained hypothesis that housing market participants exhibit extrapolative behavior when it comes to forming expectations of house prices.

We make a number of practical modifications to the derived long run equations. First, because the real user cost of capital can be negative, we do not log transform the variable, and instead freely estimate its coefficient. Second, given the lack of available data on TLA consumption, we need to proxy the per capita consumption variable (meaning that the coefficient on the proxy variable can be expected to differ from that on the per capita dwelling variable). We test three proxies for per capita consumption. First, we include a derived per capita production variable (*Prod*/*N*). This variable is derived from national industry GDP data weighted according to local TLA employment shares.[3] Since this proxy does not allow for sectoral productivity to differ across TLAs, we cannot be sure how accurate an indicator this variable is of TLA per capita incomes. Second, we include the ANZ/National Bank's quarterly index of Regional Economic Activity (*REA*) in place of consumption. This variable is available at the Regional Council (RC) level, and we attribute the same *REA* index to each TLA within an RC. This index is not an official series, but instead forms an index from a number of short run indicator variables for each region, so again we cannot be sure of its accuracy as a measure of local long run consumption. The quarterly changes in *REA* may, however, provide a useful indicator of changes in regional economic activity. Third, we include area specific fixed effects and area specific time trends (*Time*) to take account of trending per capita consumption, as well as differing amenity values and changing household size across TLAs across time. This variable accounts for any deterministic (constant) changes in incomes over time within a TLA, and allows these trends to differ between TLAs.

In estimating the long run relationship using each of these three proxies, we do not find a significant positive coefficient on $\ln(Prod/N)$. Similarly, we find no significant long run effect of the Regional Economic Activity (*REA*) variable. When we include time trends in the long run equation, the estimated coefficients on all 72 TLA time trends are positive and significant. This result is consistent with an upward trend in per capita incomes within TLAs. We therefore include the time trends to proxy for TLA specific long run per capita consumption trends in the equation.

Since house purchasers may face credit constraints, we include a proxy for the tightness of bank mortgage lending restrictions. The chosen credit restrictions proxy is the (national) ratio of non-performing loans to gross lending in the banking sector, *CR*. Higher non-performing loans lead to a reduction in bank capital and hence to a reduction in the bank's ability to advance new loans (Claus and Grimes, 2003). Accordingly, we hypothesise that as banks' bad loans across all sectors (not just housing) increase as a proportion of their loan book, they impose tighter housing equity and/or servicing covenants on borrowers, and these restrictions curb the maximum price that potential house purchasers can bid for houses. Inclusion of this variable restricts our sample period to 1996Q1 onwards. Furthermore, its inclusion (and inclusion of TLA specific time trends) means that we cannot include time fixed effects in the long run specification.

[3] This variable is not included in the final model, so is not detailed further in the data section or data appendix.

It is possible that housing assistance, provided by the Government through the accommodation supplement, may influence housing demand (and house prices) either through the "ownhome" or "renting" transfer categories. The former category provides assistance to lower income house owners to help meet mortgage payments. The latter provides assistance to lower income renters, which may induce landlords to bid higher prices for houses and then seek higher rents facilitated by renters' increased ability to service a higher rental. We test for both these possibilities. There is a strong correlation between these two related policy series (r=0.87 for the real assistance paid per recipient across the ownhome and rental categories). In the face of this issue, we test six separate definitions of the accommodation supplement (AS) variable. Each term is lagged one quarter in case the rate of assistance is driven mechanically off the current house price or rent. The variables are defined in the Data Appendix (Section B). Only one assistance variable, AS_{t-1}^{O-Real} (the real rate of ownhome assistance per recipient), is significantly positive when entered alone and/or in conjunction with other *AS* terms to the long run house price equation, so we retain this variable. (Note that the accommodation supplement term is entered as the level of the net rate of assistance, which is approximately equivalent to the log of the gross rate of assistance; i.e. $\ln(1 + AS_{t-1}^{O-Real}) \cong AS_{t-1}^{O-Real}$.)

The resulting specification of the long run housing demand (house price) equation is shown as (3), with estimation results given in Table 3.

$$\ln\left(\frac{PH_{it}}{PC_t}\right) = \alpha + \gamma_1 \ln\left(\frac{H_{it}}{N_{it}}\right) + \gamma_2 CR_t + \gamma_3 UC_{it} + \gamma_4 AS_{t-1}^{O-Real} + \lambda_i + \mu_i Time_t + \varepsilon_{it} \quad (3)$$

From Table 3, we observe that in the long run, an increase in the per capita dwelling stock (*H/N*) reduces house prices, as expected. Furthermore, higher cost of capital (*UC*) and tighter credit restrictions (*CR*) both reduce long run house prices, while an increase in the rate of accommodation supplement assistance to homeowners raises house prices. As incomes trend higher, house prices also rise (given the positive coefficients on all 72 time trends).

The residual from the long run equation is stationary according to the IPS statistic but not quite at the 1% level according to the more restrictive LLC test. It is important, therefore, to test that the error correction term is strongly significant in the short run equation.

We next consider the dynamics around the long-run equilibrium. The short run model explains the change in (the log of real) house prices as being determined by reversion towards the equilibrium house price (given any disequilibrium at the end of the previous quarter). This disequilibrium variable is denoted $\varepsilon_{i,t-1}$, which is the residual (error correction term) from the long run equation. In addition, short run house price changes may be affected by lagged changes in the variables affecting long run house prices. Thus we test for the significance of the lagged change in each variable that appears in the long run equation within the short run house price equation. We also test significance of the changes in the proxies for per capita consumption, finding that the change in per capita *REA* has a significant (short run) impact.

Table 3: Long Run House Price Estimation Results

Regressor	Coefficients
$Constant$	9.7634***
	(0.1334)
$\ln(H_{it}/N_{it})$	-2.1854***
	(0.2015)
CR_{it}	-0.0146***
	(0.0052)
UC_{it}	-0.0498***
	(0.0014)
AS_{t-1}^{O-Real}	0.0160***
	(0.0007)
Obs (1996Q3-2011Q2)	4320
$\overline{R^2}$	0.9544
LLC	-2.2762
	[0.0114]
IPS	-11.4133
	[0.0000]

Note: In this and subsequent tables, p-values are shown beneath unit root tests. Standard errors are shown beneath coefficients; ***,**,* indicates significant at 1%, 5%, 10% respectively using a conventional t-test (which is appropriate for the short run equations; but included as indicative only for long run equations). In each case, coefficients on area and time fixed effects (and area-specific time trends) are not reported. Obs is the number of observations, with the sample period shown in brackets.

The dynamic adjustment of house prices may also be influenced by short run changes in rents, leading to renters or prospective landlords bidding more for houses when rents have risen. We include lagged changes in the log of real rents per year, (R_{it-1}/PC_{t-1}), in the short run house price model. The resulting equation is shown as (4) with estimates presented in Table 4.

$$\Delta \ln\left(\frac{PH_{it}}{PC_t}\right) = \alpha + \rho\left(\varepsilon_{i,t-1}\right) + \gamma_1 \Delta \ln\left(\frac{H_{i,t-1}}{N_{i,t-1}}\right) + \gamma_2 \Delta \ln\left(\frac{REA_{i,t-1}}{N_{i,t-1}}\right) + \gamma_3 \Delta UC_{i,t-1} + \gamma_4 \Delta CR_{t-1} + \gamma_5 \Delta AS_{t-1}^{O-Real} + \gamma_6 \Delta \ln\left(\frac{R_{i,t-1}}{PC_{t-1}}\right) + u_{it} \tag{4}$$

As described in the Methodology section, three sets of estimates are presented in Table 4. The first column presents OLS estimates with conventionally-estimated standard errors. There is virtually a complete absence of serial correlation (φ ≅0). Nevertheless, for consistency with other tables of short run results, the second column presents the OLS estimates with Newey-West standard errors that are robust to the presence of autocorrelation and heteroskedasticity.

The standard errors across the two columns are very similar, consistent with the small estimated value of φ. The third column presents the SUR estimates. Again, the results are very similar to the other estimates.

The coefficient on the error correction term, with a t-value greater than 18 in absolute value, is highly significant, reinforcing the conclusion that the (restricted) long run specification represents a valid cointegrating vector. The negative coefficient on this term implies that if house prices are below (above) equilibrium last period, the current change (ceteris paribus) is positive (negative), thus bringing prices towards the long run equilibrium. In addition to the lagged residual, the (changes in) per capita dwelling stock, credit restrictions and accommodation supplement are significant with the hypothesised signs. The change in the user cost of capital has the expected sign; while not directly significant in the short run, this variable still impacts on short run house prices through the disequilibrium term.

Table 4: Short Run House Price Estimation Results

Regressor	OLS	Newey West SE's	SUR Estimates
$Constant$	0.0088***	0.0088***	0.0080***
	(0.0009)	(0.0008)	(0.0009)
$\varepsilon_{i,t-1}$	-0.1619***	-0.1619***	-0.1585***
	(0.0070)	(0.0089)	(0.0069)
$\Delta \ln(H_{i,t-1}/N_{i,t-1})$	-0.6166**	-0.6166**	-0.4339
	(0.2796)	(0.2905)	(0.2764)
$\Delta \ln(REA_{i,t-1}/N_{i,t-1})$	0.2288***	0.2288***	0.2694***
	(0.0543)	(0.0521)	(0.0537)
$\Delta UC_{i,t-1}$	-0.0017	-0.0017	-0.0018
	(0.0012)	(0.0020)	(0.0012)
ΔCR_{t-1}	-0.0736***	-0.0736***	-0.0703***
	(0.0056)	(0.0056)	(0.0056)
ΔAS_{t-1}^{O-Real}	0.0049***	0.0049***	0.0051***
	(0.0005)	(0.0005)	(0.0005)
$\Delta \ln(R_{i,t-1}/PC_t)$	0.0275***	0.0275**	0.0274***
	(0.0083)	(0.0117)	(0.0083)
φ	-0.0044		
Obs (1996Q4-2011Q2)	4248	4248	4248
$\overline{R^2}$	0.1919	0.1919	0.1915
F	145.0765***		

Note: In this and subsequent tables of short run estimates, the observation dates refer to the OLS and Newey West columns; SUR estimates are estimated over 1996Q4-2011Q2.

The (change in the) per capita REA income variable is significant and positive, as is the rents term. Since we are dealing with elasticities, the coefficients imply that a 1% rise in per capita economic activity in a quarter results in a 0.23% rise in house prices next quarter, while a

1% rise in rents in a quarter results in a small (but statistically significant) rise of 0.025% in house prices next quarter.

Together, the long and short run equations show that a higher housing stock (relative to population) places long run downward pressure on house prices. Higher user costs of capital and more stringent bank lending restrictions also place downward pressure on house prices. Higher per capita incomes and rents, in contrast, place upward pressure on house prices in the short run.

Higher rates of accommodation supplement for homeowners place upward pressure on house prices. We find no evidence that rates of rental assistance have any direct impact on house prices. However, as noted above, the rental and ownhome assistance rates are highly correlated. Accordingly, our ownhome assistance variable may be proxying for the influence of the accommodation supplement scheme as a whole. We therefore caution that the AS estimate should be considered as a broad AS scheme influence and not treated solely as an ownhome assistance estimate.

5.2. Housing Supply

The housing supply in region i at the end of time t (H_{it}) is equal to last quarter's housing stock less scrapped houses plus new houses built in t. The proportion of houses that remain from the last period (i.e. that were not scrapped) is assumed to be a TLA-specific scalar (δ_{it}). New houses built in t are assumed to equal the number of new housing consents ($HC_{i,t-j}$) granted in some period, $t-j$, (where j is the number of quarters that it takes to move from a housing consent to a completed house) multiplied by a TLA-specific scalar (θ_{it}) to represent consents not acted upon. Thus, we have the identity:

$$H_{it} = (1-\delta_{it})H_{i,t-1} + \theta_{it}HC_{i,t-j} \tag{5}$$

Given this identity, we need to explain the determinants of housing consents. Following Grimes and Aitken (2010), house builders are assumed to be price-taking profit-seeking agents within regional housing markets that are subject to shocks. New housing supply is hypothesised to be subject to quadratic adjustment costs and so does not immediately jump to match increased demand at the pre-existing price. House prices, being asset prices, jump to equilibrate short run demand and supply. The housing supply equation is based on a Tobin's Q-theory investment relationship, so supply adjusts to any disequilibrium between house prices and the full costs of construction, enabling supply to gradually adjust to observed higher demand. Over time, the prices, costs and quantities of housing and residential land adjust to re-establish long run equilibrium following a shock.

A builder seeks to build a new house where the house sale price (assumed to be equal to the price of existing houses in the region) exceeds replacement cost (i.e. the full costs of developing and building a new house). Total costs are a function of building costs and residential lot (vacant land) costs plus builders' financing costs. We assume that some substitutability exists between land and structures for a given level of utility for the ultimate purchaser, but that both sets of inputs are required for any development to proceed. Accordingly, we adopt a divisia index for total costs in TLA i at time t (TC_{it}) as a function of residential land costs (PL_{it}) and (national) building costs (PB_t) with weights summing to one. In addition, real financing costs (i_t^r) must be borne by the developer. Thus, we postulate:

$$TC_{it} = [e^{\lambda_i} PL_{it}^{\beta} PB_{it}^{1-\beta}](1 + i_t^r)^{\gamma} \tag{6}$$

where λ_i incorporates TLA-specific cost factors and γ reflects the holding period between the builder raising finance and selling the house. In equilibrium, house prices equal total costs so that $\ln(PH_{it}) = \ln(TC_{it})$. Using this equilibrium condition, and rearranging (6), we obtain the long run relationship:

$$ln\left(\frac{PH_{it}}{PB_{it}}\right) = \alpha - \beta\, ln\left(\frac{PB_{it}}{PL_{it}}\right) + \lambda_i + \lambda_t + \varepsilon_{it} \tag{7}$$

where λ_t incorporates the finance cost term and any other national factors affecting the equilibrium relationship. If (7) forms a cointegrating vector then it is valid to model housing consents relative to the housing stock (which, as shown in the data section, is a stationary variable) as a function of the (stationary) residual from equation (7).

We have estimated this equation in three different ways. First, we imposed the specification as shown in (7) where the elasticity of house prices with respect to land (β) is restricted to be identical across all TLAs. Second, we allowed β to vary according to whether a TLA is classified as urban, quasi-rural or rural (where the classifications are made according to the value of residential land to total land in the TLA as in Grimes and Hyland, 2012). Third, we allowed β to vary in an unrestricted manner and so to differ across each TLA.

The results of the three methods give similar estimates of β across TLAs and so we retain the simplest (first) specification as shown in Table 5.

According to the IPS statistic, the residuals are stationary, although this is not the case for the LLC. We therefore need to test that housing consents react significantly to the residual in the housing consents equation.

Table 5: Long-Run Housing Supply Estimation Results

Regressor	Coefficient
$Constant$	4.0169***
	(0.0184)
$ln(PB_{it}/PL_{it})$	-0.2162***
	(0.0047)
Obs (1990Q1-2011Q2)	6192
$\overline{R^2}$	0.9531
LLC	-0.8238
	[0.2050]
IPS	-8.7345
	[0.0000]

The value of β implies that a 10% increase in land costs results in a 2.2% rise in house prices. This percentage is lower than may be expected given the proportion of the house price typically observed to comprise land prices. (The β values estimated using the second approach are all slightly lower still, while the average value of β in the fully unrestricted approach varies in a similar range from -0.20 in rural TLAs to -0.25 in quasi-rural and urban TLAs.) One possible reason for the lower than expected elasticity is the presence of noise in the lot price series. As explained in the data appendix, we have smoothed lot prices to remove the worst cases of lot price data variability arising from small numbers of lot sales within a TLA. The raw lot price series for urban TLAs is much smoother than for rural TLAs (given the deeper market in more populous TLAs), but the estimated elasticity is still very similar across the various types of TLA. This suggests that data variability is not the primary contributor to the lower than expected elasticity. Another factor might be that not all lot price increases are passed through to house prices and may instead be shared between the original land owner and other participants (developers, builders and new house owners). This approach is reflected in our bargaining model for lot prices, discussed in the next section.

We explain housing consents (representing the adjustment process in the housing stock) through an error correction process consistent with Tobin's Q theory. We allow for a different speed of adjustment of housing consents depending on whether the Q-ratio is positive or negative, and in both circumstances we allow for non-linearity (convexity or concavity) in the response through inclusion of quadratic terms. Additionally, we allow price expectations and financing conditions to affect the adjustment process. Specifically, we include the extrapolated growth rates in each of house, land and building prices. The extrapolated growth is measured across the previous three years (twelve quarters) consistent with the specification in the house price equation. We also test for the impact of changes in real interest rates and credit restrictions (at national level) on housing activity. The former variable is not significant and so is omitted in the final specification, while the latter variable is significant. Increases in banks' non-performing loans may introduce greater credit restrictions to builders for developing new property, constraining housing stock growth. Incorporating these factors, we estimate the following equation:

$$\frac{HC_{it}}{H_{it-1}} - 0.6\frac{HC_{i,t-1}}{H_{it-2}} = \alpha + \gamma_1(\epsilon_{i,t-1}^{+}) + \gamma_2(\epsilon_{i,t-1}^{+})^2 + \gamma_3(\epsilon_{i,t-1}^{-}) + \gamma_4(\epsilon_{i,t-1}^{-})^2 + \theta_1 \Delta PH_{i,t-1}^{G} + \theta_2 \Delta PL_{i,t-1}^{G} + \theta_3 \Delta PB_{i,t-1}^{G} + \theta_4 \Delta CR_{t-1} + u_{it} \quad (8)$$

where the growth rates are defined as the 12 quarter geometric average growth rate, with equations for clarity appearing in Section B of Appendix 1, and where ϵ^{+} are the positive residuals from the long run Q-relationship (i.e. where house prices temporarily exceed total costs) and ϵ^{-} are the negative residuals. While HC_{it}/H_{it-1} is a stationary variable, it exhibits considerable persistence (autocorrelation). When we estimate (8) with HC_{it}/H_{it-1} as the dependent variable, we obtain a high value of φ (0.7555) indicating considerable serial correlation in the residuals. Addition of the lagged dependent variable (HC_{it-1}/H_{it-2}) to the right hand side (RHS) of (8) leads to an estimated coefficient on this variable of 0.8722 but this equation then exhibits considerable negative serial correlation (φ=-0.2574). In order to dampen this serial correlation we restrict the coefficient on the lagged dependent variable to 0.6, which we implement by choosing the dependent variable as shown in (8). Once we impose this restriction, serial correlation is virtually eliminated (φ=0.05). Table 6 presents the results.

The coefficients on the disequilibrium terms imply that the supply response initially increases slowly with a positive Q-ratio but then increases strongly as the Q-ratio rises well above equilibrium. In contrast, an essentially linear effect is observed as the Q-ratio falls below equilibrium.

Extrapolated growth in building costs is significant. While neither land price nor house price growth is significant (other than at 10% in the SUR estimate for house price growth), we retain these variables since builders' expectations may be a composite function of developments in all three prices.

Table 6: Short-Run Housing Supply Estimation Results

Regressor	OLS	Newey West SE's	SUR Estimates
$Constant$	0.0014***	0.0014***	0.0014***
	(0.0001)	(0.0001)	(0.0001)
$(\epsilon_{i,t-1}^{+})$	-0.0002	-0.0002	0.0002
	(0.0014)	(0.0023)	(0.0014)
$(\epsilon_{i,t-1}^{+})^2$	0.0237***	0.0237	0.0227***
	(0.0072)	(0.0153)	(0.0072)
$(\epsilon_{i,t-1}^{-})$	0.0037***	0.0037***	0.0038***
	(0.0013)	(0.0012)	(0.0013)
$(\epsilon_{i,t-1}^{-})^2$	-0.0003	-0.0003	-0.0006
	(0.0061)	(0.0046)	(0.0061)
$\Delta PH_{i,t-1}^{G}$	0.0002	0.0002	0.0079*
	(0.0047)	(0.0040)	(0.0047)
$\Delta PL_{i,t-1}^{G}$	0.0029	0.0029	0.0001
	(0.0025)	(0.0026)	(0.0026)
$\Delta PB_{i,t-1}^{G}$	0.0899***	0.0899***	0.0914***
	(0.0243)	(0.0251)	(0.0243)
ΔCR_{t-1}	-0.0009***	-0.0009***	-0.0009***
	(0.0002)	(0.0002)	(0.0002)
φ	0.0498		
$Obs(1996Q3 - 2011Q2)$	4320	4320	4248
$\overline{R^2}$	0.0465		0.0490
F	27.3473***		

Changes in credit restrictions are highly significant and negative as hypothesized. Thus developers and builders (who are, in practice, reliant on financiers to support their developments) are forced to scale back their activity when banks face major impairments on their own balance sheets.

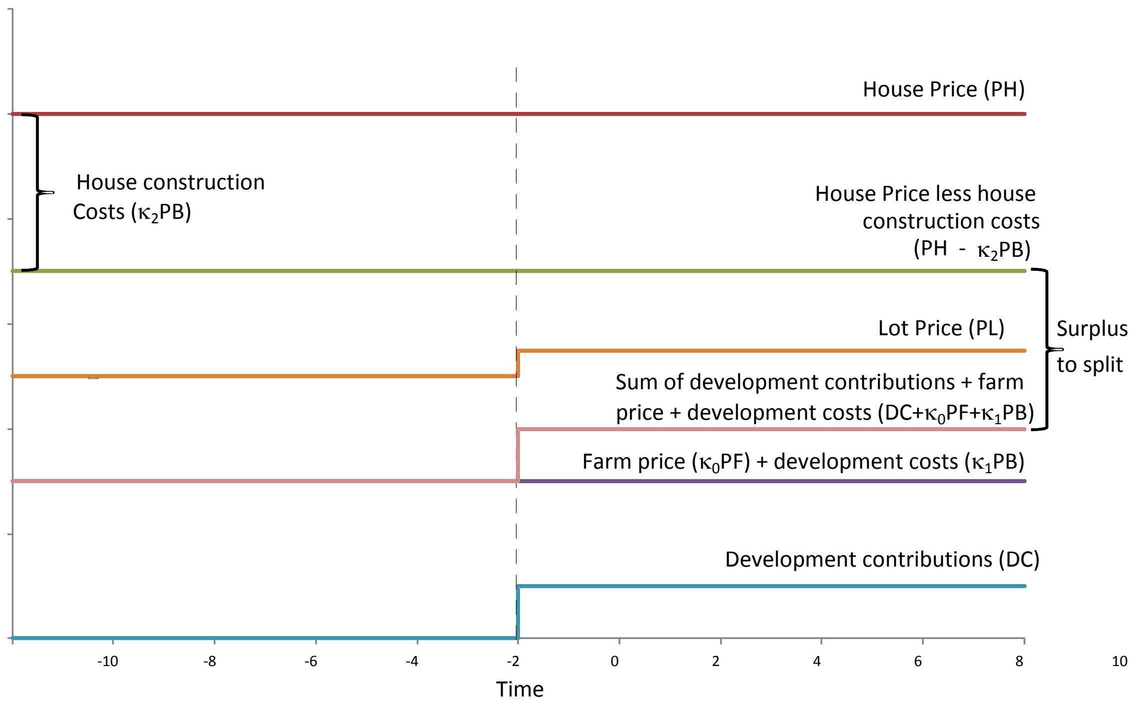
The adjusted coefficient of variation ($\overline{R^2}$) appears low in the estimates in Table 6, but this is an artifact of the construction of the dependent variable. If we estimate the equation with HC_{it}/H_{it-1} as the dependent variable (with HC_{it-1}/H_{it-2} on the RHS with a coefficient restricted to 0.6) the $\overline{R^2}$ rises to 0.5844 so that over half of the quarterly variation in building consents (relative to dwellings) is explained. Estimates (and standard errors) across the three estimation methods are similar, other than a jump in the size and significance of the coefficient on house price growth when estimated with SUR. This suggests that, in the absence of SUR estimation, there is some correlation between the residuals of the short run house price and housing consent equations. The SUR estimates account for this cross-equation correlation.

5.3. Lot Prices

A builder or the final house purchaser must purchase a vacant residential lot prior to the commencement of building a new dwelling. We assume that the builder purchases the lot from a property developer who in turn purchases the land from a farmer. This is an appropriate assumption for vacant sections on the urban fringe; we assume that lot prices interior to the urban boundary are priced in relation to lot prices on the fringe, with appropriate allowance for convenience yields.

We hypothesise that the lot price (PL) is set in accordance with a bargaining game, effectively between the farmer and the final house purchaser, with the builder and land developer as intermediaries. The latter two players are treated as silent players in the game, so we model the outcome as if driven by the two end-players (farmer and new homeowner).

Figure 2: Stylised Bargaining Game (Land Price Determinants per Lot)



The concept is captured in Figure 2 above. A farmer owns lot-sized farm land valued at $\kappa_0 PF$ (where κ_0 controls for the number of lots per farm or per hectare, depending on how the farm price, PF, is measured). She can prepare the land for residential use through incurring development costs ($\kappa_1 PB$, where PB is an index of construction costs as before) perhaps to level the land or ready it for drainage, and paying a development contribution levied under the

Local Government Act (and/or a financial contribution levied under the Resource Management Act) to the council, where the development plus any financial contribution per lot is denoted DC. (Palmon et al, 1998, discuss the way in which changes in tax rates – or development contributions – may affect property prices.)

The minimum lot price that allows for zero profit on converting farmland to residential land is therefore $DC + \kappa_0 PF + \kappa_1 PB$. In a TLA that has perfectly elastic supply of farmland with all development occurring at the periphery of an urban area, this expression will determine PL. However, some residential lot development may occur through subdivision within an urban area, especially where planning controls or geographical constraints inhibit expansion at the urban periphery (Grimes and Liang, 2009; Saiz, 2010). New lots cannot be sold to a prospective house owner at more than $PH - \kappa_2 PB$ where $\kappa_2 PB$ represents the cost of building a house on a vacant lot. The lot price will be higher the closer it is to the city centre (or other sought-after amenity); and, for any chosen lot, this convenience yield will be higher the greater is the pressure on population in the area.

We therefore hypothesise that the average urban lot price may rise above the bare minimum lot price $(DC + \kappa_0 PF + \kappa_1 PB)$ according to: (a) the level of house prices less construction costs for a new house $(PH - \kappa_2 PB)$, and (b) the impact of population pressures on land for new housing development in the presence of residential land constraints. We do not have a direct measure of explicit land supply constraints. The current TLA boundaries became operational in 1991 and (other than two cases of amalgamation) have remained unchanged thereafter. Given this institutional history, we hypothesise that the current population level relative to that in 1991 provides an indicator of relative land constraints. Accordingly, we hypothesise that the real residential lot price (PL/PC) will be set as a function of real farm prices (PF/PC), real construction costs (PB/PC), real development plus financial contributions per housing consent (DC_HC/PC), real house prices (PH/PC) and the interaction of house prices with population (N) growth relative to the 1991 population level. This final variable is modeled as: $(PH_{it}/PC_t) \times \ln(N_{it}/N_{i1991})$. This term is zero for a TLA with stagnant population, and is positive (negative) for an expanding (declining) TLA.

The development contribution variable (DC_HC) comprises total development and financial contributions paid within a TLA over a year (July-June). We normalise this amount by dividing through by the number of new housing consents within the TLA that fiscal year, and adopt that value for each quarter within the fiscal year. Three outlying observations in 2008/09, for Manukau ($59,967), Papakura ($84,488) and Waikato ($37,162) respectively, have each been capped at \$35,000 per consent; no other observations reach \$35,000 in any year for any TLA. We have tested other normalisations, including dividing through by all (residential and non-residential) building consents and by all (structure plus non-structure) building consents; the nature of the estimation results are similar in each case, albeit with differing coefficients reflecting the different normalisations. The development contribution regime began in 2002Q3 and our data begins at that date. It is possible that financial contributions were paid before that date, but we have no information on any financial contributions that were paid. Furthermore, the contribution to costs associated with new developments within a TLA effectively shifted from future ratepayers to current developers (and new homeowners) given the introduction of development contributions. This potentially changed the value of new lots as the distribution of the present discounted value of the development costs changed amongst agents. Accordingly, we allow for a freely estimated separate intercept term for each TLA covering the pre-2002Q3 period.

In modelling the lot price, we allow for the possibility that other time-varying national influences (e.g. monetary conditions, tax settings, etc) impact on lot prices, as may TLA-specific influences (e.g. sea views or geographic constraints). Thus we incorporate time and area fixed effects in our long run model. This inclusion means that the PB terms (for which only national data are available) drop out. We estimate the following long run equation where the equation is expressed in levels (rather than log-levels) to reflect the nature of the bargaining game:

$$\frac{PL_{it}}{PC_t} = \beta_1 \frac{PF_{it}}{PC_t} + \beta_2 \frac{DC\_HC_{it}}{PC_t} + \beta_3 \frac{PH_{it}}{PC_t} + \beta_4 \left(\frac{PH_{it}}{PC_t} ln \frac{N_{it}}{N_{i,1991}} \right) + \lambda_i + \lambda_t + \beta_{5,i} d_t^{t<2002Q3} + \varepsilon_{it} \tag{9}$$

where $d_t^{t<2002Q3}$ is aTLA fixed effect, equal to one for the period prior to development contributions beginning in 2002Q3 and zero thereafter. Within (9), each of β_1, β_2, β_3, and β_4 are hypothesised to be non-negative. Results are shown in Table 7.

The stationarity tests indicate that the long run real lot price equation can be treated as a cointegrating vector. As hypothesised, each of real farm prices and real development contributions are estimated to have a positive impact on real lot prices so that the minimum cost of converting farmland to residential use is reflected in price. The house price is also reflected in lot prices and this effect is exacerbated as population expands relative to the population initially within the TLA boundary. Thus a portion of the surplus between farm use and final (housing) use is reflected in lot prices. For a TLA with stagnant population, the real lot price rises, ceteris paribus, by \$361 for every \$1,000 increase in real house prices; for a TLA with a population that is twice its 1991 level, the real lot price rises, ceteris paribus, by $657 for every $1,000 increase in real house prices.

Table 7: Long Run Lot Price Estimation Results

Regressor	Coefficient
PF_{it}/PC_t	0.1401***
	(0.0389)
$(DC_{it}/HC_{it})/PC_t$	0.3792***
	(0.0764)
PH_{it}/PC_t	0.3607***
	(0.0146)
$(PH_{it}/PC_t) \times \ln\left(N_{it}/N_{i,1991}\right)$	0.4278***
	(0.0192)
Obs (1992Q2-2011Q2)	5832
$\overline{R^2}$	0.9824
LLC	-5.9868
	[0.0000]
IPS	-13.7324
	[0.0000]

A $1,000 increase in our measure of real development contributions feeds through to a $379 increase in lot prices. As discussed previously, while we know the total value of development (plus financial) contributions for each TLA, we do not know the number or type of consents to which they relate. Our measure divides total DC revenue by housing consents in the TLA in the relevant year. If instead, we divide total DC revenue by all consents issued in the TLA in the relevant year, the coefficient on DC rises towards (or above unity). Thus the exact size of the effect of a $1,000 increase in DCs relating solely to housing lots may be closer to $1,000 rather than the $379 implied by our estimated coefficient.

A $1,000 increase in farm prices per hectare is estimated to result in a $140 increase in individual residential lot prices. Taken at face value, if the full value of farmland is reflected in residential lot prices, this implies that approximately seven housing lots per hectare are developed. Given that each group of houses has to be supported by roads, parks and other amenities, this does not appear unrealistic.

We model the short run adjustment of lot prices through an error correction model, retaining additional differenced variables only where they are significant. This results in equation (10).

$$\Delta \frac{PL_{it}}{PC_t} = \rho(\varepsilon_{i,t-1}) + \gamma_1 \Delta\left(\frac{PH_{it}}{PC_{t-1}} \times ln \frac{N_{it}}{N_{i,1991}}\right) + \gamma_{2,i} d_t^{t=2002Q3} + u_{it} \qquad 10)$$

where $d_t^{t=2002Q3}$ equals one in 2002Q3 and zero otherwise, accounting for the one-off introduction of the development contribution regime. Estimation results are shown in Table 8.

Table 8: Short-Run Lot Price Estimation Results

Regressor	OLS	Newey West SE's	SUR Estimates
$\varepsilon_{i,t-1}$	-0.1842***	-0.1842***	-0.1866***
	0.0079	0.0193	0.0092
$\Delta(PH_{i,t-1}/PC_{t-1} \times \ln(N_{i,t-1}/N_{i,1991}))$	0.6260***	0.6260***	0.6049***
	0.0531	0.1256	0.0607
φ	0.0518		
Obs (1992Q3-2011Q2)	5688	5688	4248
$\overline{R^2}$	0.1065		0.1022
F	10.1660***		

The (highly significant) coefficient on the long run residual implies that a fifth of the disequilibrium in lot prices is reflected in the next quarter's change in lot prices, indicating moderately fast adjustment towards equilibrium. The only other dynamic factor affecting lot prices is house price growth interacted with population developments of the area. We find no evidence of past lot price growth (i.e. the lagged dependent variable) influencing current lot price growth so 'fad' effects are not obviously present. Furthermore, even without a lagged dependent variable, there is very little serial correlation in the residuals (φ=0.05). Explanatory power of the equation is low compared with the two previous short run equations. This likely reflects measurement noise in the lot price series. Nevertheless, despite issues with data quality, the long and short run lot price equations imply a sensible set of reactions for the lot price in response to economic and policy determinants.

A note is useful here about how the three relationships presented so far relate to one another. Consider a situation in which the system is in equilibrium and then house prices rise owing to a lift in local population. The supply equation reacts by lifting new housing consents (since Tobin's Q>1), thereby causing the stock of houses to rise over time. Residential lot prices will also rise given the lift in house prices, but this rise will not match the rise in house prices (given the estimated coefficients), so that there is still a positive supply response. The rise in housing supply will cause house prices to diminish over time through the negative impact of the dwelling stock on house prices thus leading to a new equilibrium with higher house prices, higher lot prices and a higher housing stock.

Similarly, a rise in development contributions will flow through to multiple outcomes. The initial DC rise will cause lot prices to increase, inhibiting new housing supply, so causing the dwelling stock to be lower than it otherwise would be. Thus house prices will rise over time relative to the counterfactual of no DC increase. The resulting equilibrium will see higher house and lot prices and a lower dwelling stock.

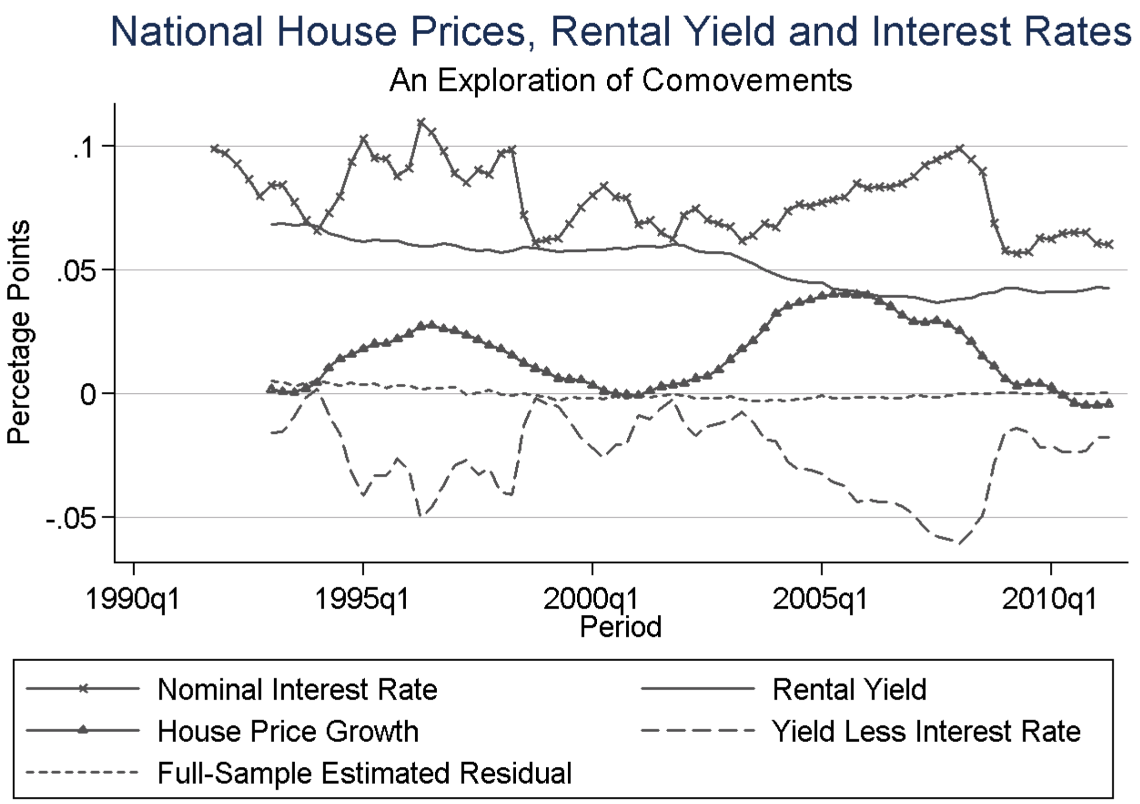
5.4. Rents

The final relationship in the model is for rents. Our model builds on that of Grimes and Aitken (2007), and incorporates insights from the model of Coleman and Scobie (2009). The former model states that the net rental yield (after depreciation and maintenance) plus expected capital gain on a rental property should equal the relevant financial market yield, being a risk free rate plus a risk premium.

Expressing rents (R_{it}) and house prices (PH_{it}) in dollar terms, with rents expressed as an annual rate (i.e. the weekly rent multiplied by 52) and expressing the annual (one year nominal mortgage) interest rate (i_t^m) as a decimal (e.g. 0.074 rather than 7.4%) we form the nominal yield difference variable, $\frac{R_{it}}{PH_{it-1}} - i_t^m$. This term represents the annual rental yield less the annual nominal interest rate. From our theory, we expect that this difference will be a function of expected capital gains on a rented house. As in the house price and housing supply equations, we assume that these expectations are a function of the extrapolated geometric growth rate over the preceding 12 quarters, PH_{it}^G.

Figure 3 graphs the (national) rental yield, the one year nominal mortgage rate, the difference between the two and (national) house price growth over the preceding three years. (One other series in the figure is explained below.) The offsetting movements between the (rental) 'yield less interest rate' and 'house price growth' are clearly apparent as predicted by theory.

Figure 3: Rental Relationships



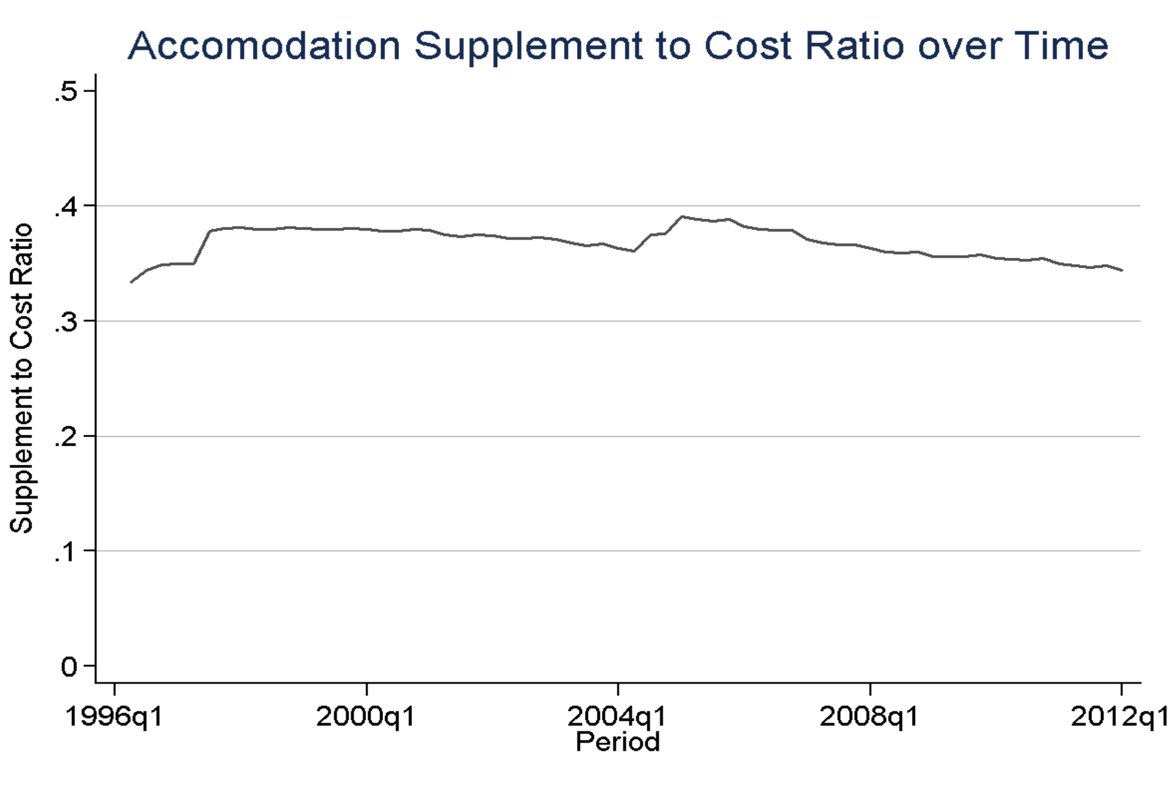
Grimes and Aitken (2007) found that the deprivation status of areas affects rental yields. Given that the deprivation status of TLAs changes little over time, we accommodate this effect through inclusion of area fixed effects.

One factor that may also affect rental yields is government accommodation supplement (AS) for renters, which provides low income renters with monetary assistance for rents. The Coleman and Scobie (2009) model can be used to derive the theoretical effect of a change in AS assistance towards renters on rents and house prices. The model shows that if the supply of new landlords is highly elastic (inelastic) then an increase in AS for renters will have little (substantial) effect on rental yields. It is therefore an empirical matter as to whether AS changes impact on the rental yield.

In practice, the AS scheme is sizeable; the average proportion of rents paid (over 1996-2012) for those in receipt of AS was over 35%. In 2012, there were approximately 200,000 renters (and over 40,000 homeowners) receiving AS. Figure 4 shows the average rate of AS received by renters relative to their rental costs per recipient since 1996. The figure shows that, whilst statistically non-stationary, the average rental AS rate is reasonably stable over time. This means that it may be difficult to ascertain the effect of the AS rate on rents even if the supply of landlords is inelastic, in which case an AS change is expected to have had a material impact on rents. (Similarly, it may be difficult to pin-point the effect of a change in ownhome AS payments in the house price equation.)

We test the long run rent relationship without inclusion of AS variables and examine whether the residual is stationary. If it is stationary, the implication is that the (non-stationary) AS terms have not had a significant influence on long run rental yields. We note, however, that the broader AS scheme does affect house prices, and therefore rents, as shown in the house price equation.

Figure 4: Accommodation Supplement Rental Assistance Rate (*$AS^{R\text{-}Rate}$*)



The hypothesised long run relationship explaining rental yields is given by expression (11):

$$\frac{R_{it}}{PH_{i,t-1}} - i_t^m = \alpha + \theta PH_{i,t-1}^G + \lambda_i + \lambda_t + \varepsilon_{it} \qquad (11)$$

The expression allows for a freely estimated coefficient on house price expectations to allow for landlords' expectations of house price growth being some proportion of the (quarterly) extrapolative price growth term, reflecting the emphasis placed on capital gains in the representative investor's asset portfolio, whilst the time fixed effects allow for a time-varying risk premium. The results of estimating (11) are shown in Table 9.

The residual from equation (11) is stationary according to both the LLC and IPS tests. We include the residuals from this long run model in Figure 3 to demonstrate the improved fit (and stationarity) of this model relative to the simple nominal yield difference.

Interest rates fell in an unprecedented manner over 2008, causing the absolute nominal yield difference to diminish sharply (which may have assisted the finding of stationarity in the model). We test whether the residual remains stationary if we limit the sample for the estimated long run equation to the pre-GFC timeframe of 1993Q1 – 2008Q1. The p-values for the residuals using both the LLC and IPS tests remain at 0.0000 for this equation when estimated over the abbreviated sample. This result provides confidence that the extraordinary events surrounding the global financial crisis are not responsible for our finding of a valid long run relationship.

Table 9: Long-Run Rental Estimation Results

Regressor	Coefficient
$Constant$	0.0007
	(0.0008)
$PH^{G}_{i,t-1}$	-0.2274***
	(0.0069)
Obs (1993Q1-2011Q2)	5328
$\overline{R^2}$	0.9285
LLC	-6.6438
	[0.0000]
IPS	-21.3897
	[0.0000]

Rent does not appear on the LHS of our long-run equation; rather the dependent variable is $\frac{R_{it}}{PH_{it-1}} - i^m_t$. We need to test that the short run adjustment process to a disequilibrium (relative to the long run equation) comes about through a change in rents (rather than in other variables) in order for us to interpret this relationship as an equation determining equilibrium rents. We cannot simply difference the LHS (as would be standard in an error correction model) and be sure that it is rents that are adjusting to any disequilibrium. Instead, we add i^m_t to the RHS, lag all RHS terms, then multiply both sides by $PH_{i,t-1}$ and difference each term to explain the change in rent levels. Similarly, we include the lagged disequilibrium term from the long run equation multiplied by $PH_{i,t-1}$ on the RHS. The lagged change in the rate of accommodation supplement rental assistance (AS_{t-1}^{R-Rate}) is added since a change in this policy variable may have a short run impact on rents (relative to house prices) as well as having a long run effect on house prices and therefore rent levels, given the stationarity of the rental yield. After dropping insignificant terms, we estimate the following short run expression, where the lagged dependent variable is added owing to the presence of serial correlation in the residuals if this term is omitted. Results are presented in Table 10.

$$\Delta R_{it} = \gamma_0 + \rho\left[PH_{i,t-1} \times \varepsilon_{i,t-1}\right] + \gamma_1 \Delta R_{i,t-1} + \gamma_2 \Delta\left[PH_{i,t-1} \times PH_{i,t-1}^{G}\right] + \gamma_3 \Delta\left[PH_{i,t-1} \times AS_{t-1}^{R-Rate}\right] + u_{it} \quad (12)$$

The coefficient on the lagged residual is highly significant in each specification confirming that the long run equation does indeed determine equilibrium rents. Lagged growth in house prices causes a rise in rents in the short term, potentially reflecting a landlord expectation of consequential rent rises.

The accommodation supplement (AS) assistance rate for renters is also estimated to have a short run impact on rental yields, consistent with a situation in which the supply of new landlords is not perfectly elastic. Landlord supply may be considerably more elastic in the long term, consistent with the finding of no AS impact on the long run rental yield. Again, we note that AS assistance for homeowners affects both short run and long run house prices, and thence rents. The same cautions regarding the interpretation of the AS effects, as noted for house prices, should be repeated here. The high positive correlation in AS support for homeowners and renters means that one should be reticent about differentiating between the support for the two types of housing. Instead, we consider it safer to analyse the impacts of the AS scheme as a whole on both rents and house prices, noting the difficulties posed by the variables for estimating the magnitude of such impacts.

Table 10: Short Run Rental Estimation Results

Regressor	OLS	Newey West SE's	SUR Estimates
$Constant$	112.0787***	112.0787***	111.8414***
	(7.5257)	(7.5266)	(7.5179)
$PH_{i,t-1} \times \varepsilon_{i,t-1}$	-0.1153***	-0.1153***	-0.1130***
	(0.0093)	(0.0114)	(0.0093)
$\Delta R_{i,t-1}$	-0.3707***	-0.3707***	-0.3718***
	(0.0145)	(0.0234)	(0.0145)
$\Delta\left[PH_{i,t-1} \times PH^{G}_{i,t-1}\right]$	0.0213***	0.0213***	0.0192***
	(0.0061)	(0.0070)	(0.0061)
$\Delta\left[PH_{i,t-1} \times AS^{R-Rate}_{t-1}\right]$	0.0107***	0.0107***	0.0106***
	(0.0021)	(0.0023)	(0.0020)
φ	-0.0744		
Obs (1996Q4-2011Q2)	4248	4248	4248
$\overline{R^2}$	0.2169		0.2168
F	295.0145***		

The other significant variable in Table 10 is the lagged change in rents. The coefficient on this variable is negative. This outcome most likely reflects noise in the rental data. For instance, a one-off temporary rise in average rents lodged within a TLA, caused by abnormal rental agreements being lodged that quarter, will not flow through to the rentals lodged in the next quarter resulting in negative autocorrelation in the quarterly change in rents. We retain this effect in our equation since this outcome is likely to be reflected in actual future observed data. These dynamics do not affect long run rental outcomes (as estimated in Table 9) and so do not affect the results of medium term simulation analysis.

5.5. Full System

Tables 11 and 12 present the full system results for the long run and short run equations respectively. The short run estimates that we present are those obtained using the SUR estimation method given that this approach takes account of all available information across the four equations. The correlation matrix of cross-equation residuals following SUR estimation indicates very low cross-equation residual correlation, with correlation coefficients varying between 0.0076 and 0.1036.

Table 11: Long Run Equations

	House Prices	**Housing Supply**	**Lot Prices**	**Rents**
	$\ln\left(\frac{PH_{it}}{PC_t}\right)$	$ln\left(\frac{PH_{it}}{PB_{it}}\right)$	$\frac{PL_{it}}{PC_t}$	$\frac{R_{it}}{PH_{i,t-1}} - i_t^m$
$Constant$	9.7634*** (0.1334)	4.0169*** (0.0184)		0.0007 (0.0008)
$\ln(H_{it}/N_{it})$	-2.1854*** (0.2015)			
UC_{it}	-0.0498*** (0.0014)			
CR_{it}	-0.0146*** (0.0052)			
AS_{t-1}^{O-Real}	0.0160*** (0.0007)			
$\ln(PB_{it}/PL_{it})$		-0.2162*** (0.0047)		
PF_{it}/PC_{it}			0.1401*** (0.0389)	
$(DC_{it}/HC_{it})/PC_t$			0.3792*** (0.0764)	
PH_{it}/PC_{it}			0.3607*** (0.0146)	
$(PH_{it}/PC_t) \times \ln(N_{it}/N_{i,1991})$			0.4278*** (0.0192)	
$PH_{i,t}^G$				-0.2274*** (0.0069)
Obs	4320 1996Q3-2011Q2	6192 1990Q1-2011Q2	5832 1991Q1-2011Q2	5328 1993Q1-2011Q2
$\overline{R^2}$	0.9544	0.9531	0.9824	0.9285
Area fixed effects included	Y	Y	Y	Y
Time fixed effects included	N	Y	Y	Y
Area specific time trends included	Y	N	N	N
$d_t^{t<2002Q3}$ included	N	N	Y	N

Table 12: Short Run Equations (SUR Estimates)

	House Prices	Housing Supply	Lot Prices	Rents
	$\Delta\ln\left(\frac{PH_{it}}{PC_t}\right)$	$\frac{HC_{it}}{H_{it-1}} - 0.6\frac{HC_{i,t-1}}{H_{it-2}}$	$\Delta\frac{PL_{it}}{PC_t}$	ΔR_{it}
$Constant$	0.0080***	0.0014***		111.8199***
	(0.0009)	(0.0001)		(7.5179)
$\varepsilon_{i,t-1}$	-0.1585***		-0.1866***	
	(0.0069)		(0.0092)	
$\Delta\ln(H_{i,t-1}/N_{i,t-1})$	-0.4339			
	(0.2764)			
$\Delta\ln(REA_{i,t-1}/N_{i,t-1})$	0.2694***			
	(0.0537)			
$\Delta UC_{i,t-1}$	-0.0018			
	(0.0012)			
ΔCR_{t-1}	-0.0703***	-0.0009***		
	(0.0056)	(0.0002)		
ΔAS_{t-1}^{O-Real}	0.0051***			
	(0.0005)			
$\Delta\ln(R_{i,t-1}/PC_{t-1})$	0.0274***			
	(0.0083)			
$\varepsilon_{i,t-1}^{+}$		0.0002		
		(0.0014)		
$(\varepsilon_{i,t-1}^{+})^2$		0.0227***		
		(0.0072)		
$\varepsilon_{i,t-1}^{-}$		0.0038***		
		(0.0013)		
$(\varepsilon_{i,t-1}^{-})^2$		-0.0006		
		(0.0061)		
$\Delta PH_{i,t-1}^{G}$		0.0079*		
		(0.0047)		
$\Delta PL_{i,t-1}^{G}$		0.0001		
		(0.0026)		
$\Delta PB_{i,t-1}^{G}$		0.0913***		
		(0.0243)		
$\Delta(PH_{i,t-1}/PC_{t-1} \times \ln(N_{i,t-1}/N_{i,1991}))$			0.6050***	
			(0.0607)	
$PH_{i,t-1} \times \varepsilon_{i,t-1}$				-0.1130***
				(0.0093)
$\Delta R_{i,t-1}$				-0.3716***
				(0.0145)
$\Delta(PH_{i,t-1} \times PH_{i,t-1}^{G})$				0.0192***
				(0.0061)
$\Delta(PH_{i,t-1} \times AS_{t-1}^{R-Rate})$				0.0106***
				(0.0020)
Obs (1996Q4-2011Q2)	4248	4248	4248	4248
$\overline{R^2}$	0.1915	0.049	0.1022	0.2168
$d_t^{t=2002Q3}$ included	N	N	Y	N

No area fixed effects, time fixed effects or area specific time trends are included in the short run specifications.

6. Simulations

We subject the model, as characterised in Tables 11 and 12 (long run and short run equations respectively), to a series of policy and other exogenous shocks.[4] In each case, the shocks are treated as being permanent, but the model could equally consider temporary innovations. The exogenous variables subject to (independent) shocks are: a 5% increase in population (N) of the TLA, a tightening in credit restrictions proxied by a 2 percentage point (pp) increase in banks' non-performing loans ratio (CR), a 10% fall in national construction costs (PB), and a 20% increase in farm prices per hectare (PF). The policy variable shocks considered are: a doubling in the rate of development plus financial contributions (DC_HC), a 10% increase in accommodation supplement for both ownhome ($AS^{O\text{-}Real}$) and rentals ($AS^{R\text{-}Rate}$), and an expansion in the effective land area available for development proxied by a 5% decrease in the 1991 population (N_{1991}). Each of these shocks is run for the final five years of our sample (i.e. from 2006Q3 to 2011Q2) with the simulated shocked outcomes compared to a baseline without the shock.[5] These shocks are conducted for a single TLA, Manukau, which is a major housing growth area in the south of Auckland, but the shocks could also easily be applied to any other TLA.

We add simulations of the housing market effects of the Christchurch earthquakes. Here we simulate the impacts of changes to a number of the exogenous variables acting together (e.g. destruction of the housing stock and a relocation of population). Given the inter-connectedness of the shocks and resulting population movements within the broader Christchurch urban area, we simulate the effects of the earthquake on the housing outcomes both of Christchurch City by itself and across the three urban TLAs: Christchurch City, Selwyn and Waimakariri. The range of simulations covering the earthquake is discussed in more detail below.

For each simulation, we present four graphs relating to our four estimated relationships. Each of the price graphs (nominal house prices, nominal lot prices, and the average rent) shows the time-path of the variable without the shock from 1993 onwards, together with the simulated (shocked) path of the variable from 2006Q3 onwards. The first graph for each simulation shows the time-path of both the number of housing consents and the dwelling stock over the same period, each with their respective simulated path given the shock. (The dwelling stock is

[4] Owing to the recursive nature of the model, these simulations can all be easily programmed and run in Excel. The recursive structure means that any shock (other than to a modelled variable) has its initial effect on the modelled variables in the quarter following the shock.

[5] The baseline is the predicted path of each variable; i.e. the actual variable less estimated residuals over the five year period.

measured on the left hand axis and dwelling consents are measured on the right hand axis of the graph.)

6.1. Increased Population Level (Figure 5)

In our first simulation we consider an exogenous 5% increase in the Manukau population, which could be reflective of internal migration from Canterbury to Auckland following the earthquakes, or increased immigration at the national level. Such a figure is not much greater than the annual percentage change of population observed in Manukau from 2002Q2-2003Q2.

Population changes have two direct effects on the housing market in this model. Given a population increase, the per capita stock of housing is reduced below the baseline counterfactual. With an increased population, but a fixed number of dwellings in the short-run, there is upward pressure on house prices. Similarly, land availability per person is reduced, so residential lot prices are bid up.

In the long-run, arbitrage forces house prices to be set equal to the cost of replacement. The change in Manukau population in 2006Q3 implies a 2.74% increase in equilibrium land prices, ceteris paribus. Given the estimated parameters, we expect a 0.59% appreciation of house prices in the long-run from the supply side equilibrium. Developers will take advantage of the short-run disequilibrium and new construction should rise until the equilibrium relationship with house prices is restored. The housing stock will increase to almost completely accommodate the larger population base.

Thus house prices should tend towards the baseline after an initial jump, with a permanently higher dwelling stock and land prices. However adjustment in all areas is slow and lagged. With both house prices and land prices below their long-run equilibrium following the shock we observe an adjustment upwards in prices in the subsequent period, such that both house and land prices increase relative to their baseline comparisons by 3.88%.

House prices will continue to increase relative to the baseline until the dwelling stock has risen by almost the same amount as population. The higher rate of consents only partially reduces the inflationary pressures on house prices, which exceed the baseline comparison by a maximum 14.10%, occurring in the 14th quarter after the shock. This increase flows through to land prices and rents. The percentage difference between the simulated and baseline land prices and rents is strictly increasing over time, leading to a difference 19 quarters after the shock of 11.63% and 5.94% respectively.

As suggested, the inflationary pressures on land prices are not sufficient to completely offset the house price appreciation. Relative house price appreciation leads to more consents than predicted under the baseline case. Housing consents under the simulated case exceed the baseline by as much as 33.58% in the 8th quarter following the shock, and remain 24.14% higher than the baseline in the final quarter. This leads to an increase in the simulated dwelling stock, which exceeds the baseline by 0.87% after 5 years, a long way short of the 5% required to restore the per capita housing stock to its pre-shock level. This simulation highlights the slow adjustment of the housing stock, and hence the housing market, resulting in substantial persistence of shocks.[6]

6.2. Tighter Credit Restrictions (Figure 6)

We simulate the effect of a two percentage point increase in the ratio of banks' non-performing loans to total assets (*CR*). This increase compares with the actual 1.81 p.p. increase in banks' non-performing loans between 2007Q3 and 2011Q1. An increase in CR translates into tighter credit restrictions imposed by banks on borrowers.

The tighter credit restrictions affect housing market outcomes through two direct channels in the model. First, house-buyers face tighter credit restrictions (that may be exhibited, for instance, through lower maximum loan to value ratios) as a result of the deterioration in bank balance sheets; this places direct downward pressure on house prices. Second, builders/developers face greater credit restrictions when attempting to access loans to develop new dwellings; this places direct downward pressure on dwelling consents (new house construction) and hence downward pressure on the dwelling stock and thence upward pressure on house prices. These two channels therefore place competing pressures on house prices, while both channels have the effect of reducing the rate of new dwelling construction.

Nominal house prices fall by 13.51% in the period following the shock, as house-buyers bid less for houses in the face of tighter credit restrictions. The reduced house prices flow through to reductions in lot prices and rents. Dwelling consents fall by 59.80% in the subsequent period, which is the maximum difference from baseline over the 20 quarters following the date of the shock. This effect is only temporary (albeit prolonged) as credit restrictions only bite on housing investment in the short run. Nevertheless, there is a prolonged impact on the stock of residential dwellings given that the simulated investment in new dwellings is below baseline for five years after the onset of the shock. The reduction in the stock of dwellings (relative to

[6] An extended simulation reveals that the housing stock increases by approximately 5% (i.e. catches up with the population surge) after approximately eight years, at which point the elevated level of new housing consents returns to its baseline path.

baseline), in the face of unchanged population, causes upward pressure on house prices, with the effect that house prices return to baseline after five years.

Lot prices similarly return to baseline after five years, following their initial fall, reflecting the house price dynamics. Rents fall initially along with house prices but do not return fully to baseline after five years. Thus the rental yield is below baseline after five years, reflecting the (temporary) rise in capital gains on housing (relative to baseline) during the catch-up phase as house prices return to their baseline level. Longer term, as house prices resume their prior trajectory, the rental yield will also return to its baseline level. The dwelling stock remains well below baseline after five years, reflecting the depressed nature of new construction over the five year interval.

Overall, the simulated initial 13.51% reduction in house prices arising from the shock is in the same order as the (actual) 15.33% reduction in (peak to trough) real house prices observed nationally following the rise in banks' non-performing loans after the global financial crisis (GFC). Furthermore, the 59.80% initial reduction in dwelling consents in this simulation compares with the 56.04% reduction in national dwelling consents following the GFC. Thus the model appears to replicate the broad impacts of the GFC on key variables. The important insight thereafter is that prices (and dwelling investment activity) rebound in response to the disequilibria that the credit shock initiates, although the dwelling stock remains well below its baseline level after five years.

6.3. Lower Construction Costs (Figure 7)

The New Zealand Productivity Commission (2012) report highlighted New Zealand's apparent high level of construction costs. We consider the results of an increase in the competitiveness of domestic housing construction by exogenously reducing the domestic construction cost index by 10%. Increased construction costs should increase lot prices, to prepare farm land for residential use. This means the indirect effect of higher construction costs on construction activity, through higher land prices, acts to amplify the direct effect. Given we model lot prices with time fixed effects we cannot also include the national construction cost index. As a result we present a conservative estimate of the impact of construction cost shocks.

A reduction in building costs flows through to lower replacement costs for housing. As demand remains unchanged in the short-run, previously marginal developments are now desirable. Developers react accordingly and we estimate that consents initially increase above baseline by 10.87%.

As the housing stock increases there is downward pressure on prices, and this process will continue until the greater per capita housing stock acts to re-equilibrate house prices relative to (the lower) replacement cost. Consents remain above the counterfactual for the entire 5-year window, remaining 16.24% above the counterfactual after five years. This translates to an ever increasing housing stock, which is 0.98% greater than the baseline estimate at the end of the sample period.

The increasing housing stock leads to downward pressure on house prices, which are 1.65% below baseline at the end of the period. This fall is well short of the 7.84% decrease in house prices implied by the long-run housing supply equation; thus housing consents will remain above baseline for an extended period beyond 2011Q2.

6.4. Higher Farm Prices (Figure 8)

Farm prices form part of the lower bound to vacant residential lot prices, and hence influence the replacement cost of housing. In this scenario we consider how a 20% increase in the representative Manukau farm price, perhaps driven by higher international commodity prices, flows through the system. National farm prices rose by 67.80% between 2002Q2 and 2003Q4 as world commodity prices increased markedly, so the magnitude of this shock is realistic.

An increase in farm prices raises the floor of residential lot prices. In the period following the shock, lot prices rise by just 0.04%. This highlights that lot prices are set near the top of the surplus interval in the bargaining game; thus there is little impact from changing the lower bound. In the long run, land prices increase by 21.88% of the change in farm prices, other factors equal. The 20% increase in farm prices over the counter factual is around a $6,000 increase, thus we expect only a $1,200 appreciation of lot prices. As a result, it is unsurprising that there is little impact of the farm price increase on lot prices, with lot prices increasing by a maximum 0.22% 12 quarters after the shock, and finishing just 0.20% above the baseline at the end of the period.

With little impact on land prices we estimate virtually no change in the time profile of house prices or rents. In addition, there is only a small response in housing consents; the increased land prices and slow adjustment of house prices reduces the profitability of new developments. Housing consents decline by a maximum 0.19%, and remain 0.07% below the baseline at the end of the period.

6.5. Higher Development Contributions Charges per Consent (Figure 9)

We consider the impact on the Manukau housing market of a 100% increase in the rate of development contributions, which equates to an increase in the rate per consent of between $22,000 and $35,000 depending on the financial year.

A higher rate of developer contributions per building consent increases the long-run lot price. Land purchasers begin to build the higher costs into the lot sales price, and we see a 0.45% (or $1,583) increase in land prices above the baseline in the subsequent period. The long-run coefficient on developer contributions per consent ($DC_{it}_HC_{it}$) is 0.4658, thus we would expect land prices to continue to increase until they realise almost half the increase in development contributions. Accordingly, the percentage difference in lot prices from baseline is increasing over much of the period, reaching a maximum increase of 3.15% in the 18th quarter after the shock, and remaining at approximately that level in the final quarter of our sample. However, the absolute difference is always increasing, reaching $12,496 in the final period which represents 39% of the change in the rate of development contributions per consent, reflecting almost the full long run effect.

As land prices rise, the profitability of building new dwellings is reduced and developers react by reducing housing consent applications; simulated housing consents are 2.44% below baseline after three and a half years, and remain 0.9% below baseline in the final period.

There are offsetting effects, however. As the number of consents falls, the dwelling stock is reduced below the baseline comparison, placing upward pressure on house prices (and rents). This house price appreciation slows down the decline in consents. However house prices are only 0.09% above baseline in the final period. Comparing this to the 0.68% long run appreciation implied by the 3.14% appreciation of land prices, it implies that consents will remain below baseline for a substantial period until house prices finally reach equilibrium.

6.6. Increased Accommodation Supplement Receipts (Figure 10)

Our sixth simulation considers the effect that increasing government assistance for housing services has on the housing market. Specifically, we consider a 10% increase in both the average real Accommodation Supplement receipt per "ownhome" recipient (AS_t^{O-Real}), which equates to an increase of between $7.60 and $8.10 per week depending on the quarter, as well as the proportion of a renter's accommodation bill that is met through Accommodation

Supplements (AS_t^{R-Rate}) which translates to an increase in the rate of between 3.48 and 3.79 percentage points.[7]

The higher homeowner transfer level is realised as a higher level of income that can only be spent on housing. This results in a higher long run house price, which begins to increase in the second period after the shock. The higher rate of assistance to renters puts short run pressure on rents, but in the long run rents are governed by house prices and market returns, thus ownhome assistance indirectly leads to higher rents.

House price appreciation puts upwards pressure on residential lot prices via the long run lot price equation. However, this is a relationship between price levels, and thus is insufficient to restore the equilibrium supply relationship. As a result, there is a disequilibrium in house prices and it is increasingly desirable to build new dwellings. Housing consents rise quickly to be a maximum of 41.73% above the baseline in the 7th quarter after the shock, and remaining relatively stable thereafter to stay 35.51% above baseline in the final period of our sample. This increased construction leads to a stock of housing that is 1.13% above baseline (which translates to an additional 1181 homes).

The increased supply acts to constrain house prices. Regardless, house prices exceed the baseline comparison at a maximum of 17.82% in the 7th quarter after the shock, and remain 15.58% above the baseline in the final quarter. This drives land to reach as much as 10.53% above the base line in the 18th quarter after the shock, and rental prices to be 7.19% above baseline in the final quarter. These values suggest that house prices remain significantly above their replacement costs, thus we should continue to see an adjustment in the housing stock for a period well beyond our 5 year window.

The simulated price (and resulting supply) responses to this shock are well above those that we would anticipate if house prices rose to impound the present discounted value of the increased assistance. In estimating the effects of accommodation assistance on house prices and rents, we noted the difficulties of colinearity between the different AS measures and the potential effects of endogeneity in which AS policies were potentially adjusted in light of lagged house price and rental movements. We attempted to overcome the latter by using a lagged value for AS in our equations, but this may not have entirely dealt with the issue. We also noted the lack of variation in our AS measures which makes it difficult to pin down the magnitude of responses to

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[7] This increased rental assistance rate is applied to rents (and house prices) that are raised by the increase in ownhome assistance so there is an element of double-counting in that respect. Since the rental assistance rate only affects short run outcomes, any double-counting dissipates completely in the long run.

an AS change. Our assessment is that the simulated responses to the AS increases considerably overstate the impacts of an AS increase on house and land prices, rents and new housing supply, although the direction of effect in each case is as expected.

6.7. Effective Increase in Land Availability (Figure 11)

Actions to constrain or free-up land have direct effects on housing market outcomes. This simulation considers the implications of reducing the constraints on land available for residential use. Our proxy for land constraints in the model is the ratio of a TLA's population to its 1991 population level, where 1991 corresponds to the timing of the setting of TLA boundaries. Accordingly, the reduction in constraints is proxied by a 10% increase in Manukau's 1991 population, in turn implying a greater degree of land available for development.

The additional land immediately puts downward pressure on land prices, which initially fall by 0.86% relative to baseline. The estimated long run fall is a 2.74% reduction in land prices given the 2006Q3 house price, other factors constant. The lower level of land prices acts to increase housing consents; developers arbitrage the difference between the house price level and its value implied by the lower cost of replacement. Thus we see housing consents increase by 2.56% relative to the baseline two periods after the shock.

The higher level of consents flows through to the housing stock with a two period lag, which puts downward pressure on house prices for a given population level, and this reduction in house prices feeds back to further decrease land prices. With the coefficients estimated within the model, the convergence to equilibrium between house prices and replacement costs is gradual. Thus we see that housing consents remain above equilibrium across the entire 5 year forecast window, exceeding the baseline case by as much as 7.02% in the 6th quarter after the shock. Thereafter, housing consents retrace towards the baseline level but still remain 1.54% above baseline in the final quarter of our sample.

The increased level of development pushes the dwelling stock above baseline by 0.17% in the final quarter, placing downward pressure on house prices. House prices fall over the period due to the increased stock of dwellings and are 0.34% below their baseline value in the final period.

Land prices trend downward relative to baseline over the simulation period as a result of falling house prices and of the adjustment to the new long run equilibrium implied by lower land constraints. As a result, land prices are 5.10% below baseline in 2011Q2. Falling house prices also drive rents down, but given that there is only a small effect on house prices in this scenario, we identify only a small differential in rents, which are below baseline by just 0.08% in the final quarter.

Overall, therefore, this simulation indicates that land availability primarily has impacts on the price of land and on the supply of new dwellings, but has little short to medium term impact on other housing outcomes. The impacts on house prices and rents will increase in the longer term as the dwelling stock continues to increase. Again, however, the lags in the system are sizeable owing to the time it takes for new dwelling construction to have a material impact on the size of the dwelling stock.

6.8. Christchurch City Dwelling Shock (Figure 12)

We consider the simulated response of a one-off 5% destruction of the Christchurch City housing stock, coupled with a one-off 5% reduction in land supply (proxied by a 5% reduction in N_{1991}). In order to isolate the pure housing market responses, we hold all other variables (such as population) at their baseline levels in this simulation; housing and population changes across the broader Christchurch urban area are considered in the next simulation.

Given that the housing stock is a slow moving variable, and prices adjust to equate demand and supply, the destruction of such infrastructure has significant and long lasting effect on housing market outcomes. The exogenous destruction of a portion of the dwelling stock leads to a lower level of per capita housing, which results in upward pressure on house prices to restore equilibrium. There is also an immediate adjustment of land prices, given the effective tightening of land restrictions.

After an initial fall in housing consents immediately following the shock, housing consents quickly react to the disequilibrium that has been created and exceed the baseline by as much as 20.95% in the 14th quarter after the shock, remaining 17.50% above baseline in the final period of our sample. (Note that no delays due to seismic, engineering, insurance or other matters are incorporated into the simulation.) Increased construction gradually reduces the strain on dwellings per capita, but the difference in the dwelling stock from baseline is still 4.14% after five years.

The rising stock of dwellings acts to partially constrain house prices, which rise quickly following the shock, reaching a maximum differential over baseline of 14.78% in the 14th quarter after the shock, and tending slowly towards baseline thereafter.

Given that the constraint on land availability has effectively tightened, the long run price of land increases. Model parameters indicate that a 5% reduction in land availability should increase the equilibrium land price by 3.40% given the 2006Q3 house price, other factors constant. Of course other factors are not constant, and the increasing house prices lead to additional temporary upward pressure on land prices, such that lot prices exceed the baseline counterfactual by 12.10% in the final quarter of our sample. However the pattern appears to level off, and as house prices return to equilibrium we expect land prices to stabilise near 3.40% above the baseline. What is clear from the simulation is that given the rate of (increased) dwelling consents, it will take far longer than five years to bring the Christchurch housing market back to equilibrium.

6.9. Christchurch Earthquake (Figures 13–15)

In our final simulation we replicate some of the quantitative effects of the Christchurch earthquake, and examine the implied impacts across the Christchurch urban area, i.e. Christchurch City TLA, and its two neighbouring districts, Waimakariri and Selwyn. The major earthquake in Canterbury on 4th September 2010, and subsequent aftershocks, left an estimated 6,812 dwellings in Christchurch City and 1,048 homes in the Waimakariri District uninhabitable, which reflect 4.50% and 5.49% of our 2010Q3 estimated dwelling stocks respectively. With few homes affected in the Selwyn district, we consider a one-off destruction of the dwelling stock of Waimakariri, Christchurch City and Selwyn in 2006Q3 of 5%, 5% and 0% respectively.

Not only were some dwellings destroyed, but some residential land was also deemed unfit for future use, thus we have an immediate contraction of available land. To capture this effect we reduce the 1991 population by the same amount as the dwelling stock reduction in each TLA to reflect lower land availability per person. We note however, that land is being freed up in the Christchurch urban periphery, and thus a more dynamic land availability shock may be more realistic.

Following the Christchurch earthquakes, much of the Christchurch CBD was inaccessible affecting employment. An exodus from Christchurch has resulted, with the population of the Christchurch City TLA estimated to fall by 8,900 (or 2.4%) in the year to June 2011. However, this does not capture intended population change, as lengthy insurance settlements and other factors have constrained migration. To consider the permanent effect on population, we use the difference in Statistics NZ's sub-national population forecasts for 2016 published in February 2010 and October 2012 respectively, attributing the entire difference to the Christchurch earthquakes. This reflects a 4.43% reduction in the 2016 projected Christchurch TLA population, a 0.56% reduction in the projection for Waimakariri, and a 2.65% increase in the projected population of Selwyn. These numbers (which we round to -5%, -1%

and +3%) highlight the degree of migration within Canterbury, as well as towards other areas such as Auckland and Australia.

The number of residents wishing to reside in an area may be more important than the observed population level in determining housing market outcomes. If the housing stock and population who wish to reside in Christchurch both reduced by 5% we would expect little change in market outcomes, as the per capita stock of housing is unchanged. However, a number of individuals leave because they cannot find housing. They bid up the price of housing in an attempt to purchase, but the housing stock is lower and fixed, thus accommodation must be found elsewhere for some individuals. In this regard, we believe that this scenario will be useful for considering the short to medium term impacts of the Christchurch earthquakes on Selwyn and Waimakariri, but perhaps a better case for the short-run implications in the Christchurch City TLA is implied by the scenario shown in Figure 12 where there is a destruction of the housing stock, but no population adjustment. In the long-run, the population and dwelling stock should adjust, leading to a scenario closer to that which is portrayed under this scenario.

A related caveat is that with an inaccessible CBD there may have been a real reduction in local activity, which would feed through to incomes. The NZRHM uses linear trends to control for income in the long run, thus we cannot consider the effect of income changes on housing markets. If we were to consider short-run pressures, the resulting depression of local activity would feed through to a temporary reduction in local demand. Conversely, increased population flows into the neighbouring TLAs may lead to increased local activity in those areas. We believe it would be misleading to consider short run effects without the long run comparison, and thus hold per capita incomes constant.

We also note that this model may under-estimate the impact on the Christchurch rental market for two reasons. First, the rental stock may have been disproportionately affected by the earthquake, and secondly, there may be extra short term pressures from tradespeople operating in Canterbury requiring only temporary accommodation. We are unable to model, with confidence, the impacts of these idiosyncratic factors.

As hypothesised, there is little impact of the shock on some of the housing market outcomes of the Christchurch City TLA, portrayed in Figure 13. The equivalence of the dwelling stock and population changes leaves housing demand unchanged, thus house prices fall below baseline by a maximum of 0.15% over the forecast period, occurring in the 15th quarter after the shock. Stable house prices lead to stable rents. Furthermore, with the change in population equivalent to the change in land availability there is no change in long run land prices.

As a result, the change in housing consents completely reflects the stationary housing investment rate. There is no disequilibrium that can be extracted by developers, and so housing consents remain around 5% below baseline for the entire forecast period. This implies that the dwelling stock will remain 5% below the baseline counterfactual thereafter, (given that population is held exogenous).

The story is quite different in the neighbouring districts of Waimakariri and Selwyn. With a 5% rate of dwelling destruction and a contraction of land availability by the same amount, coupled with a 1% reduction in the population level, Waimakariri experiences real impacts as a result of the earthquake. This is depicted in Figure 14.

Given that there is more destruction of the dwelling stock than the change in population there is a reduction in per capita housing which requires an appreciation of house prices to stifle the excess demand. We estimate house prices increase 3.24% in the period following the shock, which will continue to rise reflecting gradual adjustment.

Land prices also rise, reflecting an effective reduction in land availability per person. In the period following the shock, land prices rise by 4.32% relative to the baseline, and this is expected to increase over time due to the partial adjustment displayed in our short-run equations. However, there exists an interdependency between land and house prices such that as one increases so too does the other. As a result, house prices are increasing throughout much of the forecast period, reaching a maximum deviation from baseline of 11.56% in the 14th quarter after the shock, and remaining 10.8% above baseline in the final period of our sample. Land prices rise across the entire period, sitting 13.25% above the baseline in the final period. Increased house prices must also be reflected in rents; we estimate Waimakariri rents increase across the forecast period, sitting 4.98% above the baseline in the final quarter.

Equilibrium between the house price and its component costs requires that house price changes reflect 22% of the relative changes in land prices. With house prices much more responsive to the shock than land prices, developers will increase building to exploit the disequilibrium. After an initial fall, reflecting the lower level of consents required to maintain the smaller housing stock, the disequilibrium in house prices relative to costs leads to increased consents, such that consents exceed the baseline by 17.21% in the 8th quarter after the shock, remaining 12.73% above baseline in the final period. The estimated construction levels nevertheless lead to a housing stock which remains 4.31% below the baseline in the final period of our sample.

Given there is no change in the dwelling stock or land availability in Selwyn, the impact of the earthquake shock in this district is analogous to the population shock (Figure 5). This can be seen in Figure 15. Increased population levels lead to upward pressure on house prices and land prices, ceteris paribus. We find that in the period following the initial shock there is a 2.33% and 3.84% appreciation of house and land prices respectively. With house prices rising by more than the long-run change implied by the land price change, consents rise to meet the increased demand and so reduce the disequilibrium between house prices and component costs. Consents rise relative to the baseline across the entire sample period such that consents are 23.29% above baseline in the final period, which leads to a dwelling stock that is 0.55% greater that the baseline by the final period. The increasing stock ultimately reduces some of the pressure on house prices, which sit 8.44% above the counterfactual in the 14th quarter following the shock, remaining 7.83% above the counterfactual in the final period. House price appreciation, combined with population change, combine to push land prices 10.79% above the counterfactual in the 17th quarter after the shock, remaining at around this level through to the final quarter. Rents rise to reflect the increased costs, sitting 3.73% above baseline in the final quarter.

The NZRHM suggests that Waimakariri and Selwyn will experience a shortage of housing for an extended period, which will be reflected in house and land prices as a result of the Christchurch earthquakes. The implications for Christchurch City, from the previous simulation, flow from the short-run constraints on population flows and the destruction of housing and land. Together, these will lead to a significant degree of upward pressure on prices and construction. However, if population adjusts downwards in the long run, prices should return towards baseline, with a permanently lower stock of housing thereafter.

Figure 5: Simulation of Manukau Population ↑ 5%

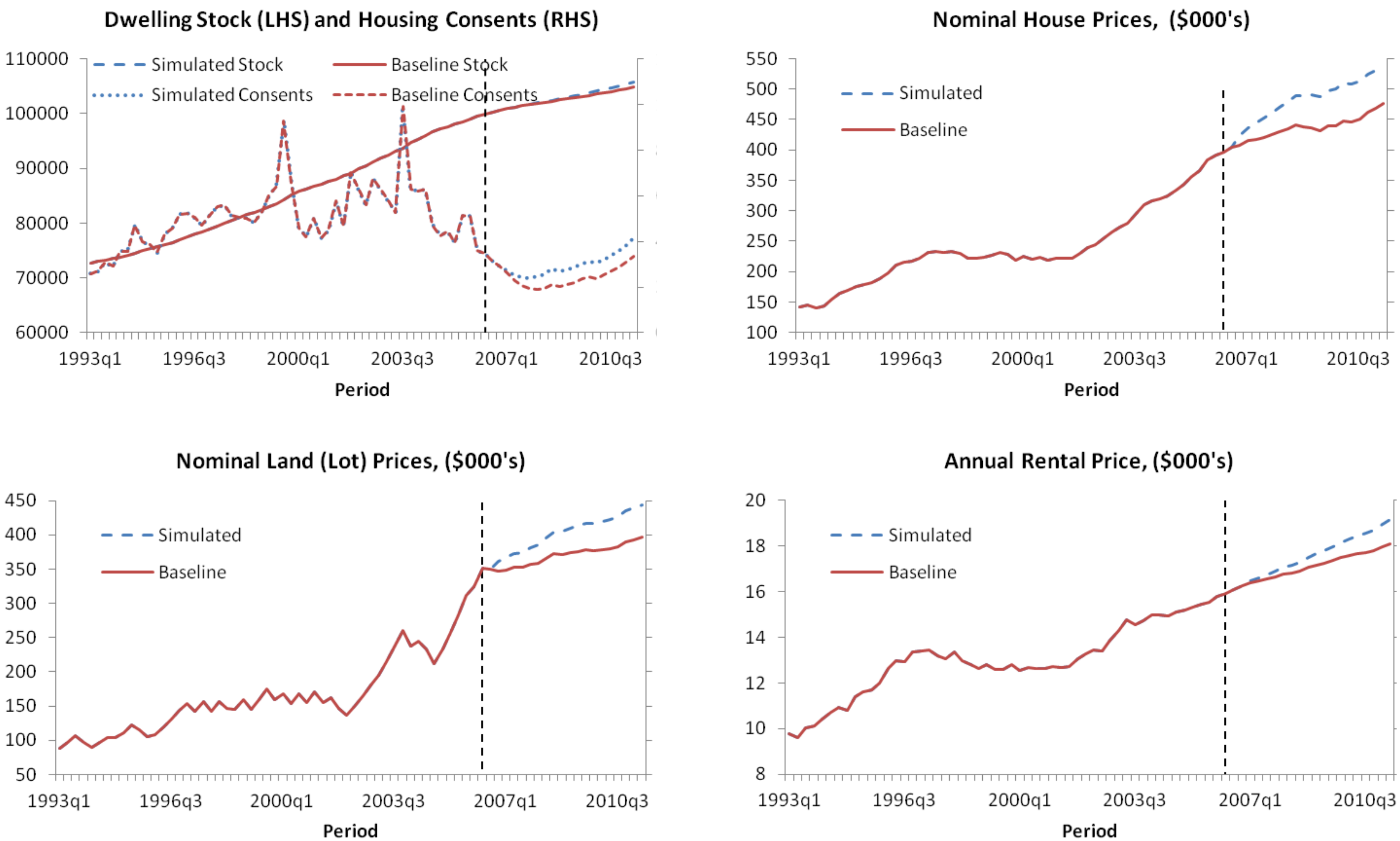


Figure 6: Simulation of National Non-Performing Loans Ratio ↑ 2pp

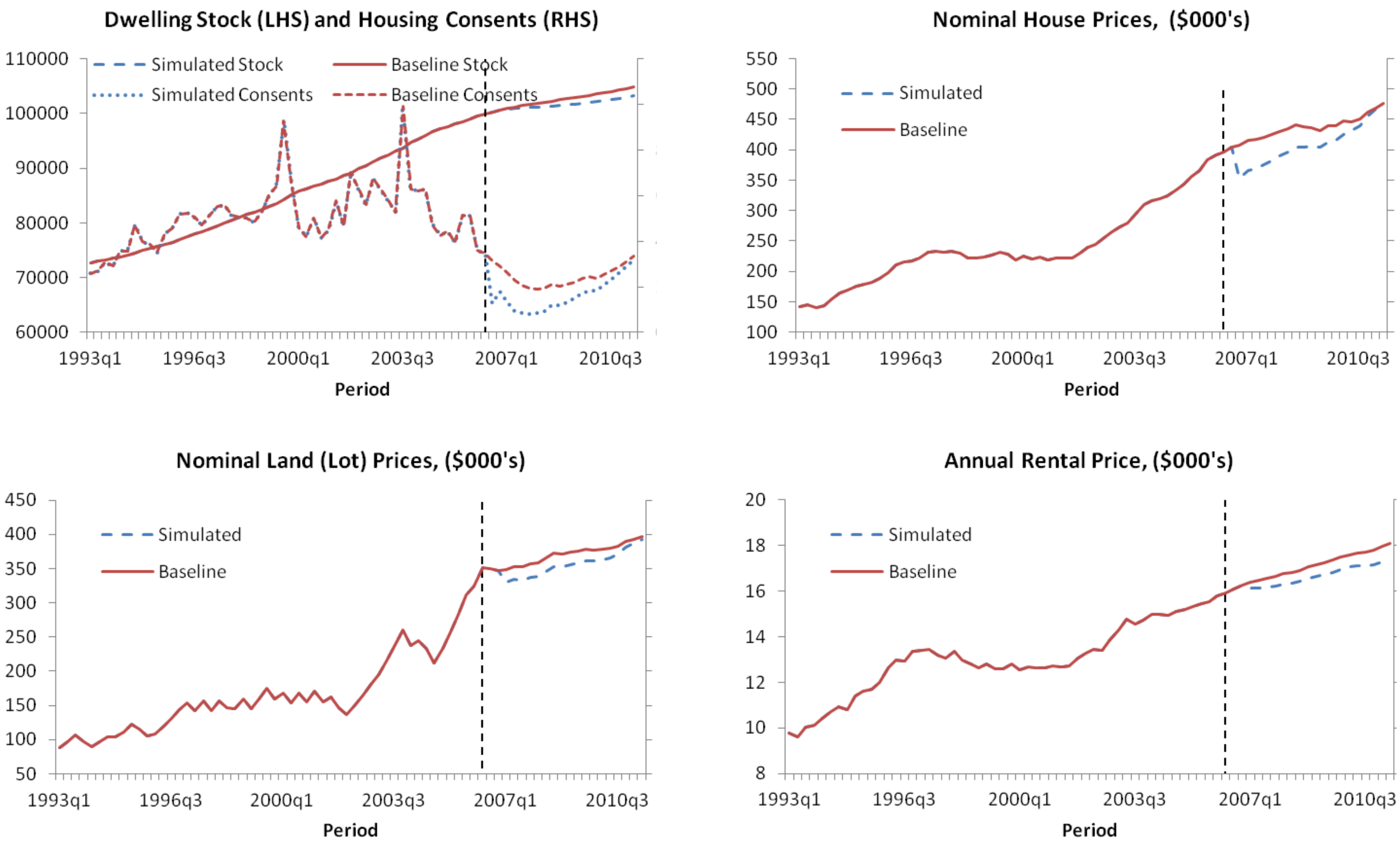


Figure 7: Simulation of National Construction Costs ↓ 10%

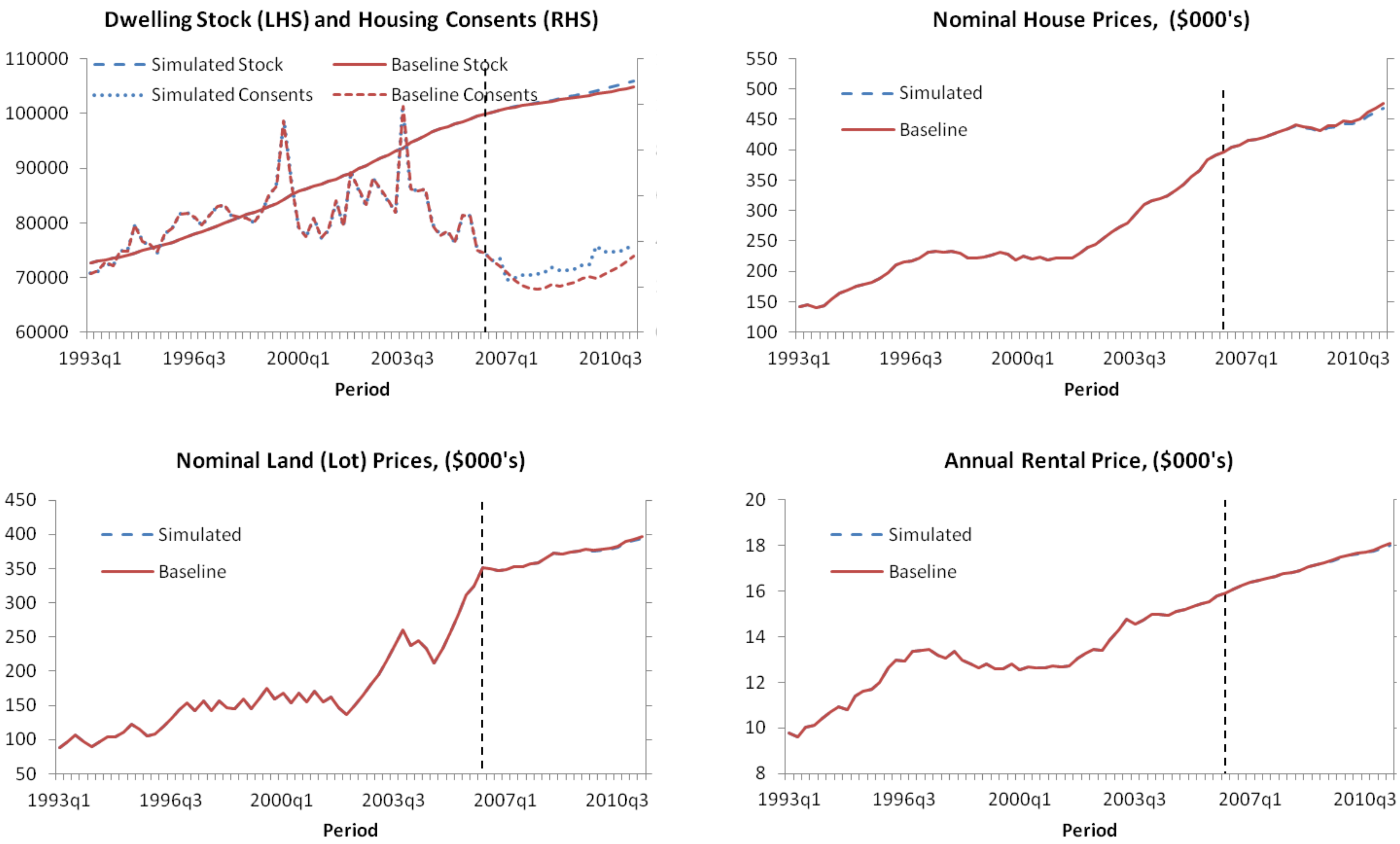


Figure 8: Simulation of Manukau Farm Price ↑ 20%

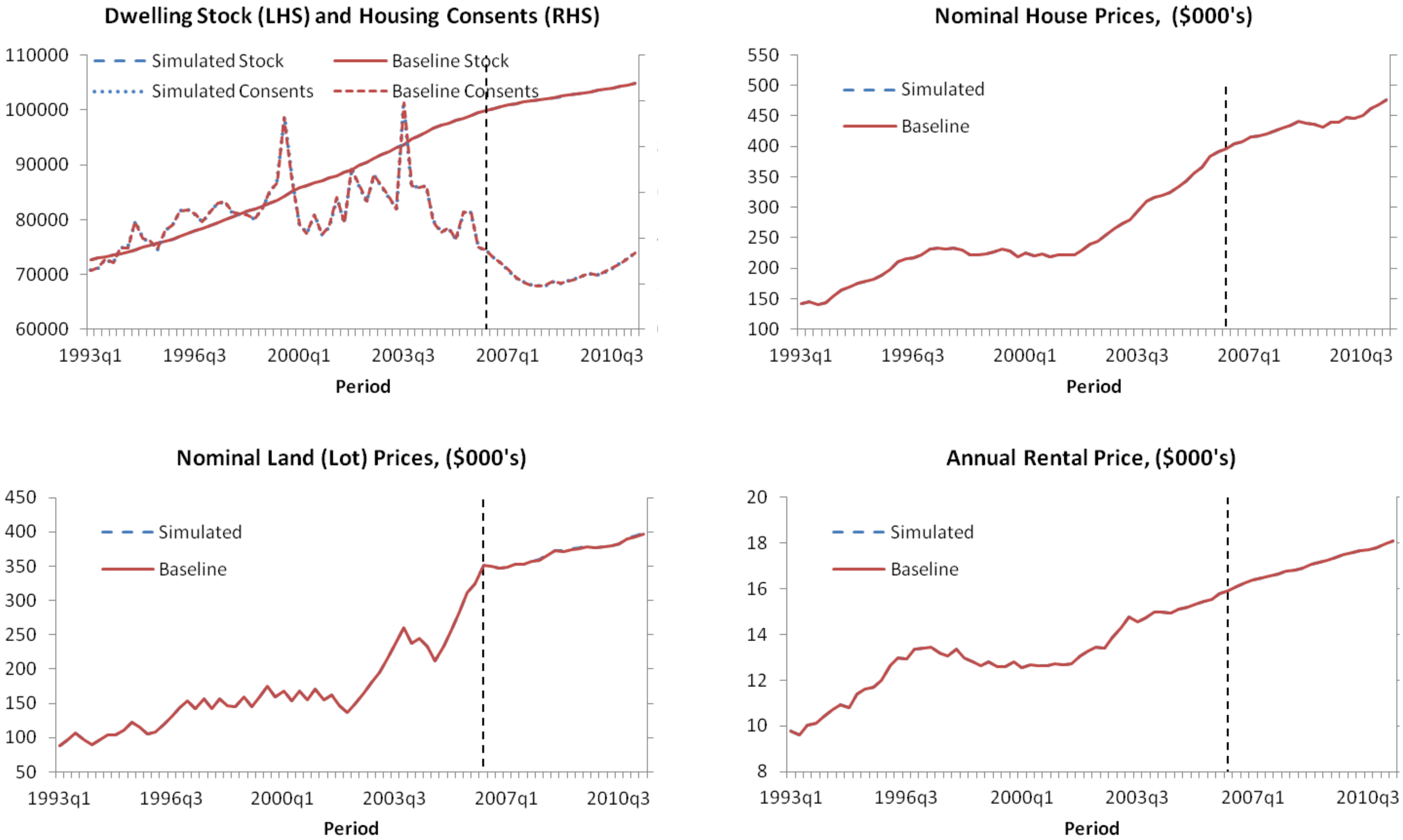


Figure 9: Simulation of Manukau Developer Contributions per Housing Consent ↑ 100%

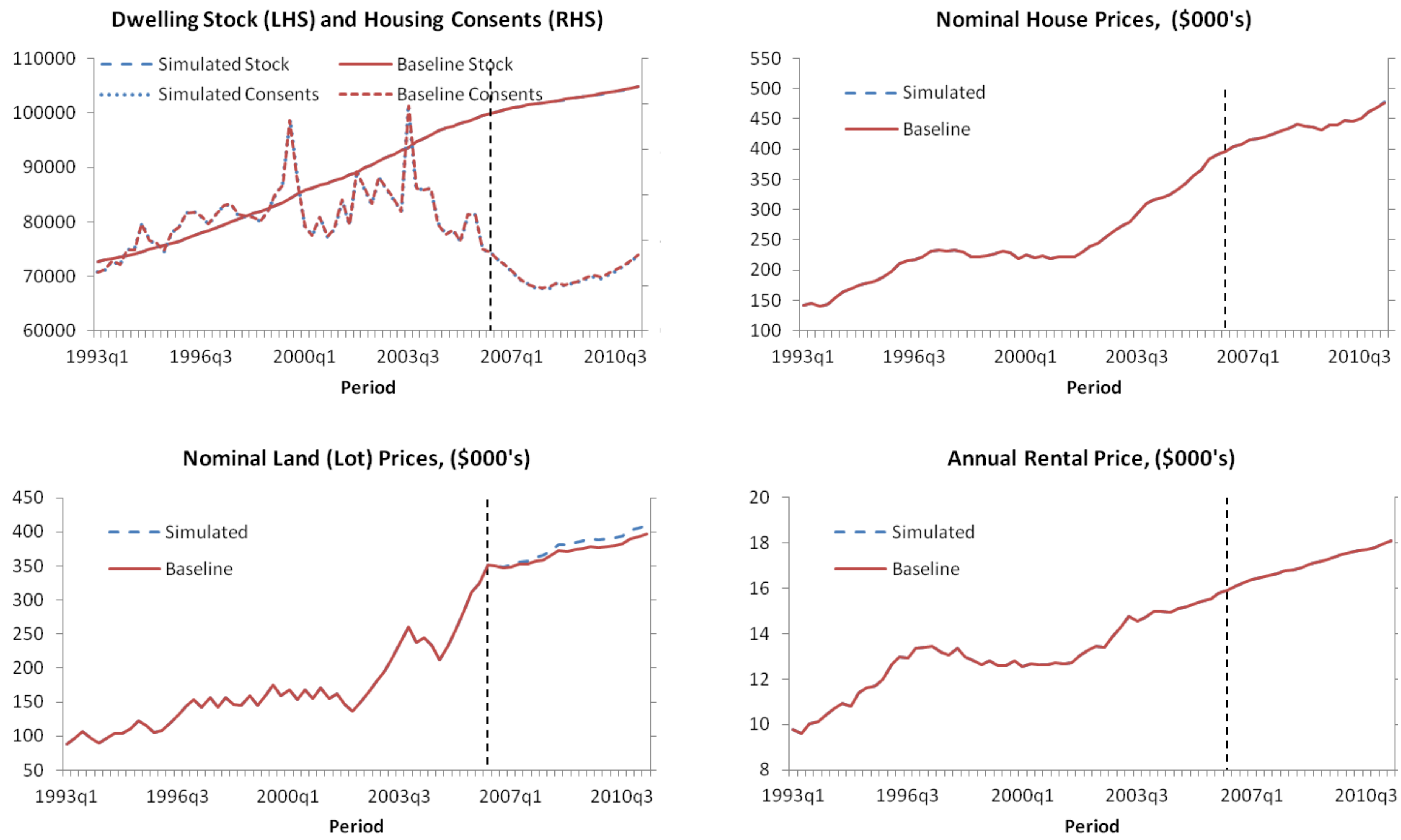


Figure 10: Simulation of National Accommodation Supplement Receipts ↑ 10%

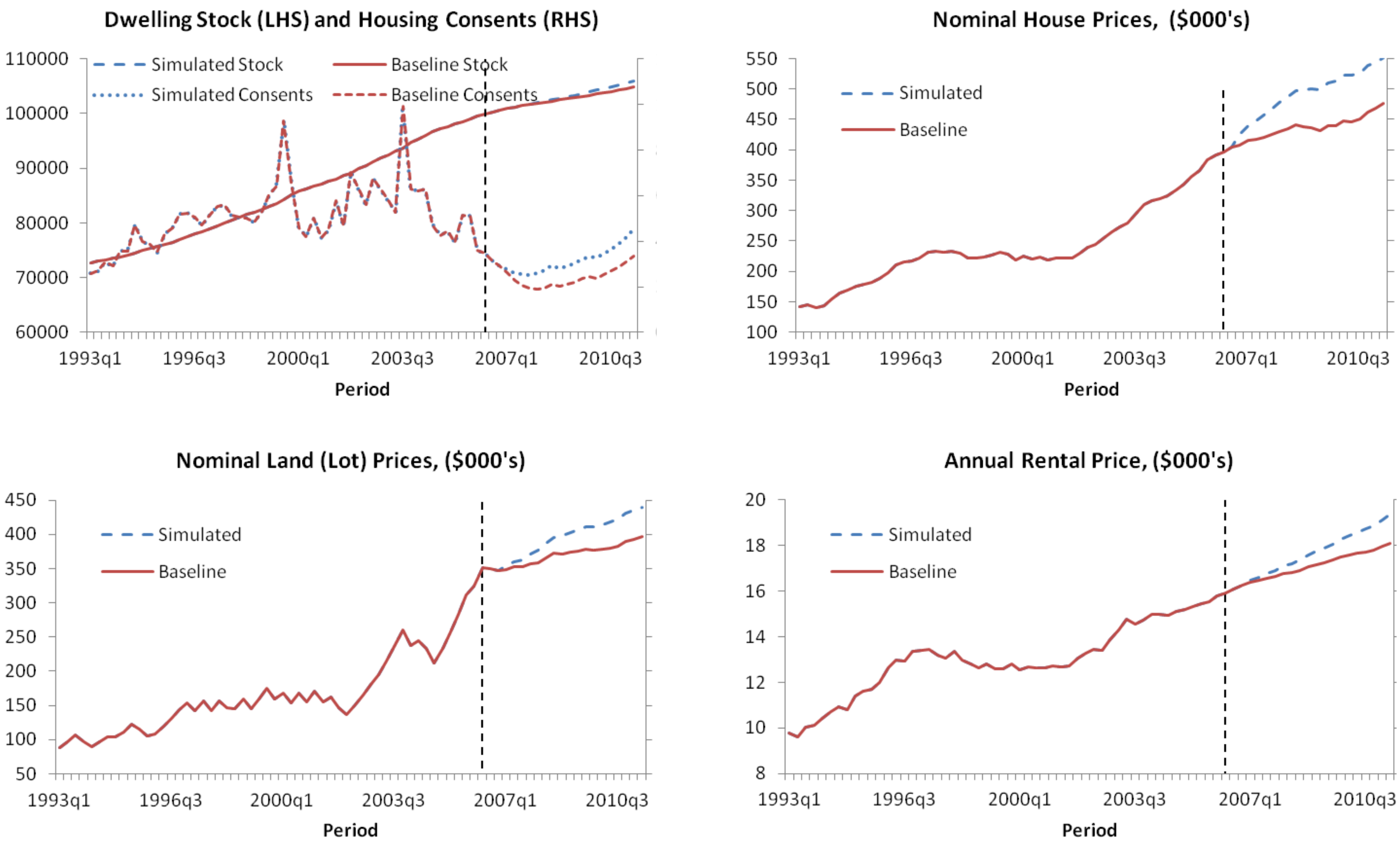


Figure 11: Simulation of Manukau Land Availability ↑ 10%

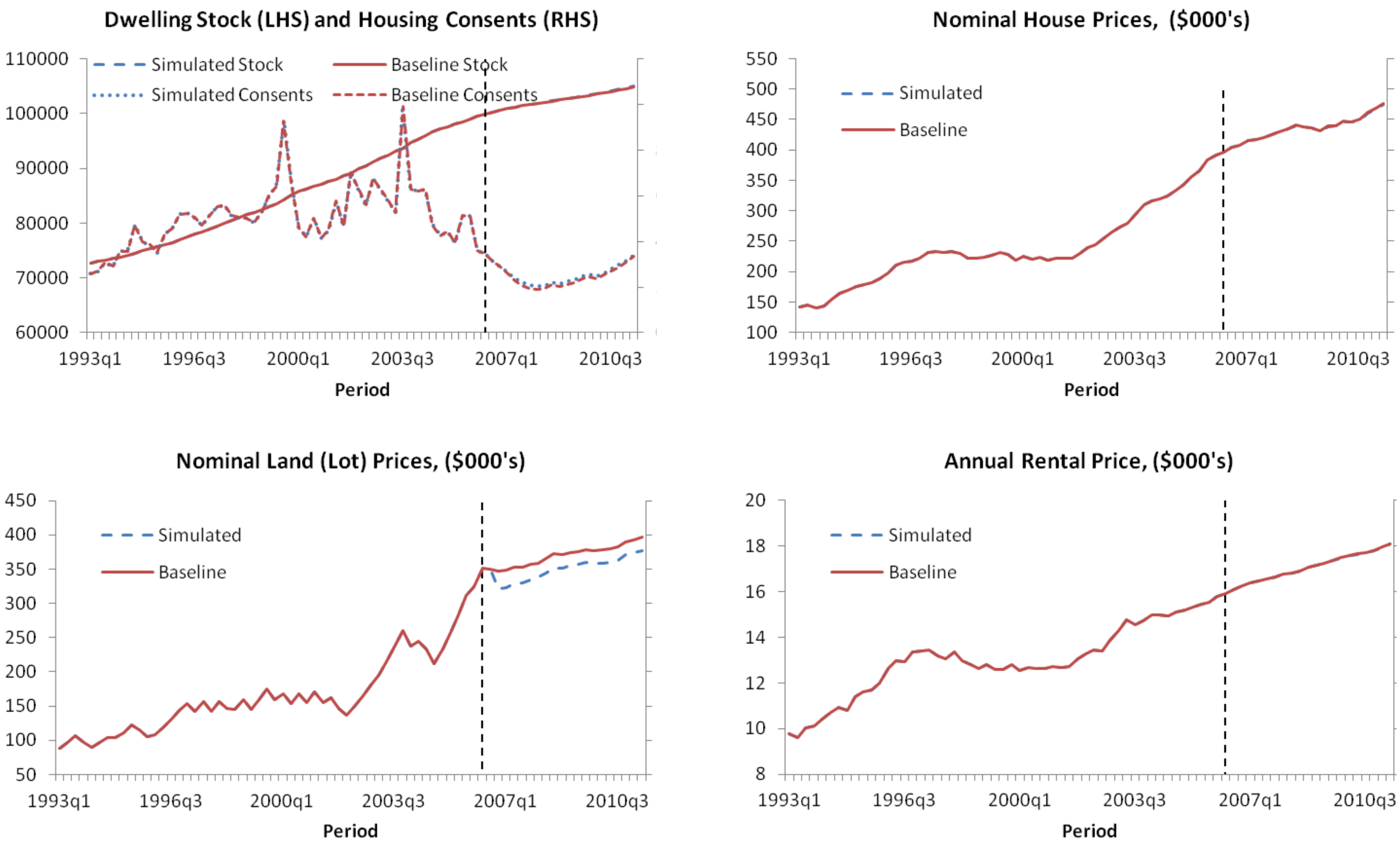


Figure 12: Simulation of Christchurch Dwelling Stock (and Land Availability) ↓ 5%

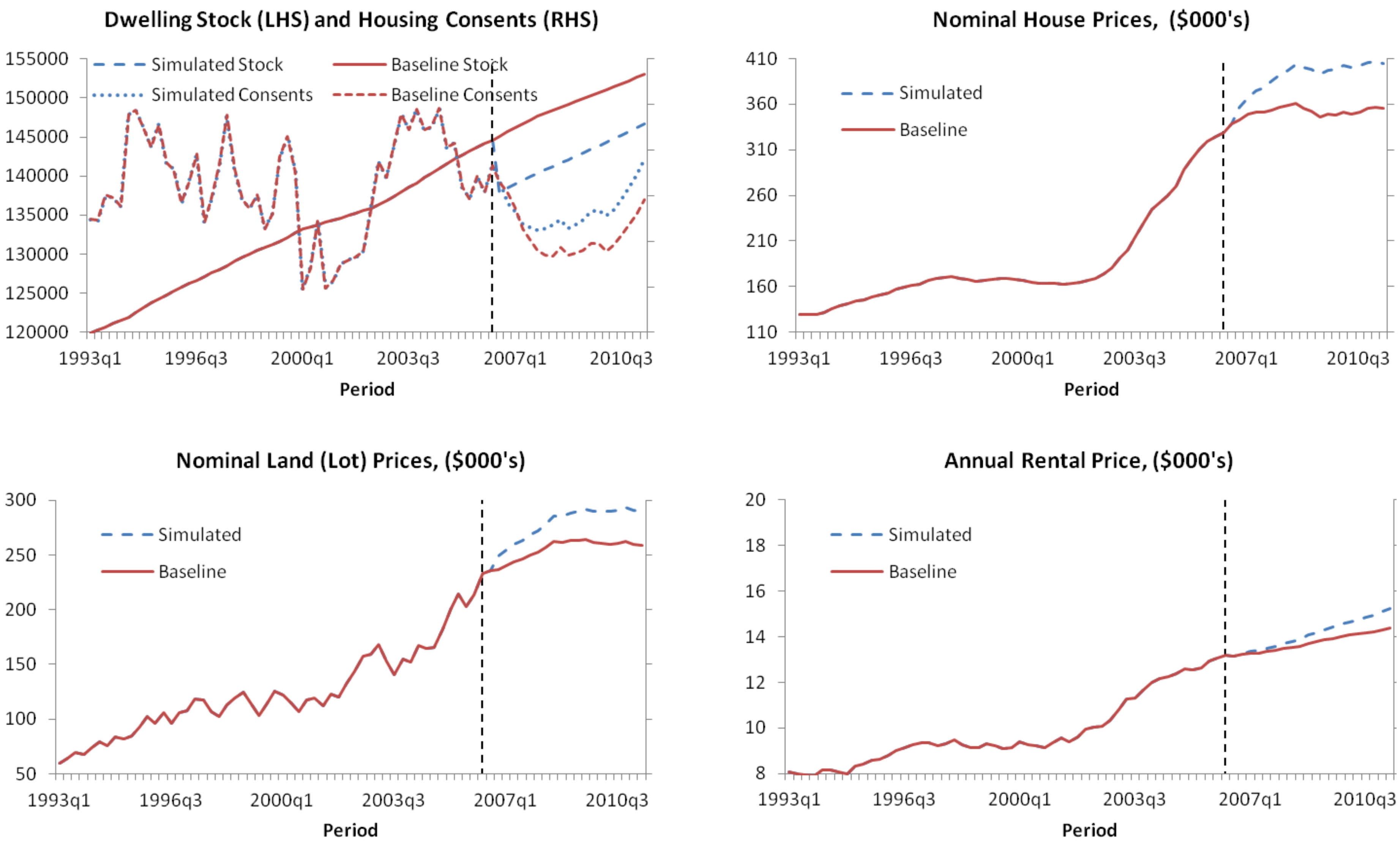


Figure 13: Simulation of Impact of a Christchurch earthquake on Christchurch

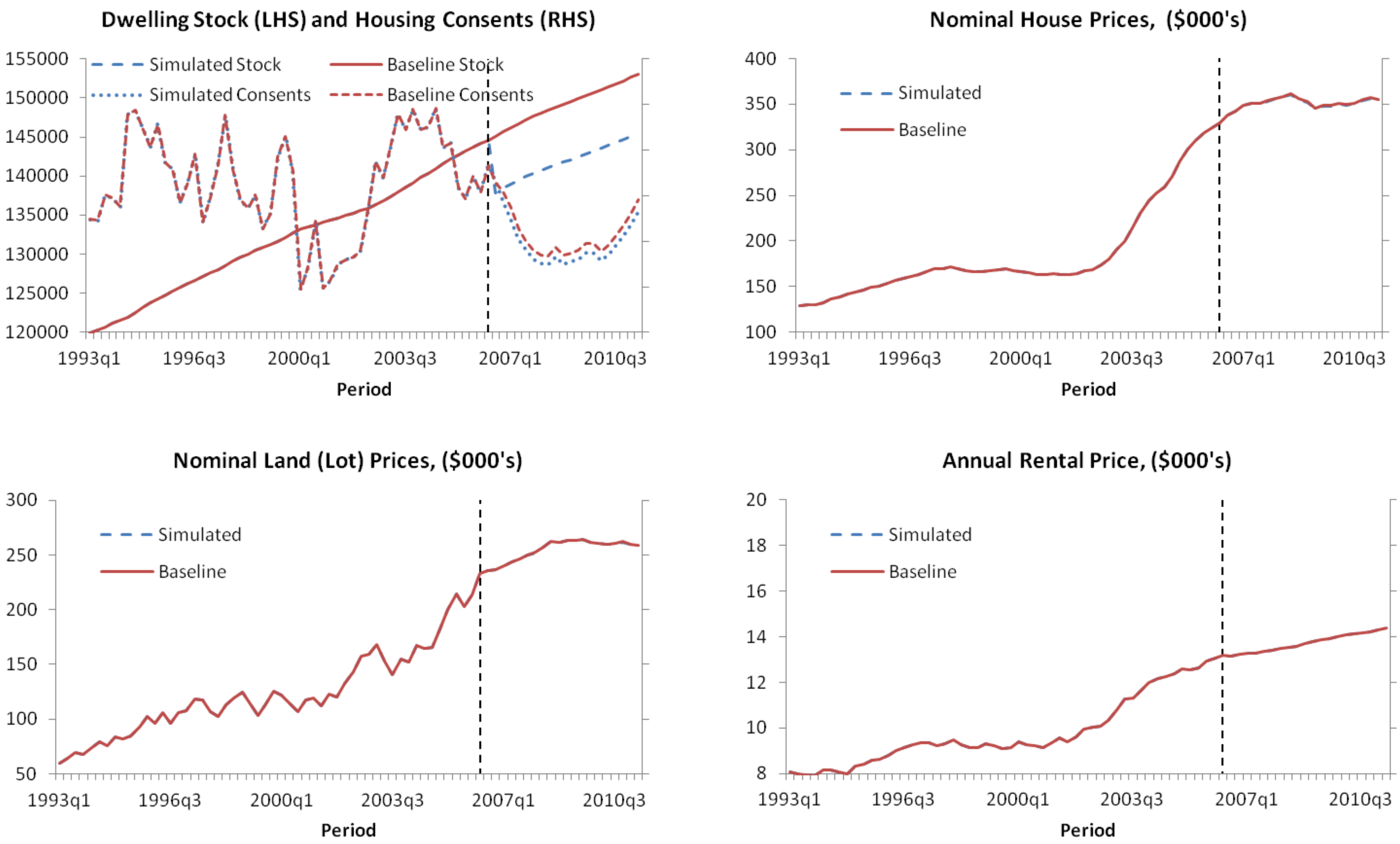


Figure 14: Simulation of Impact of a Christchurch earthquake on Waimakariri

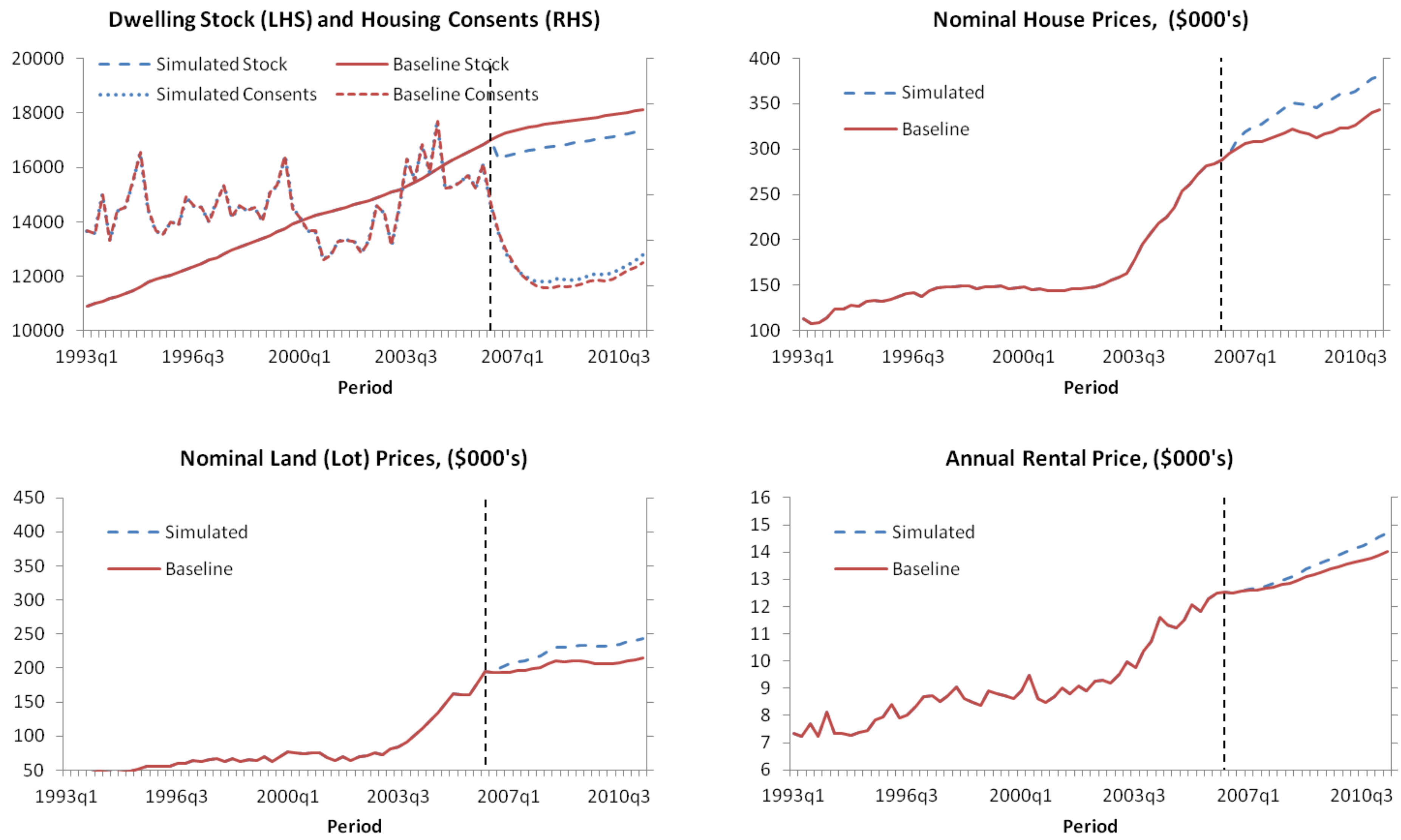
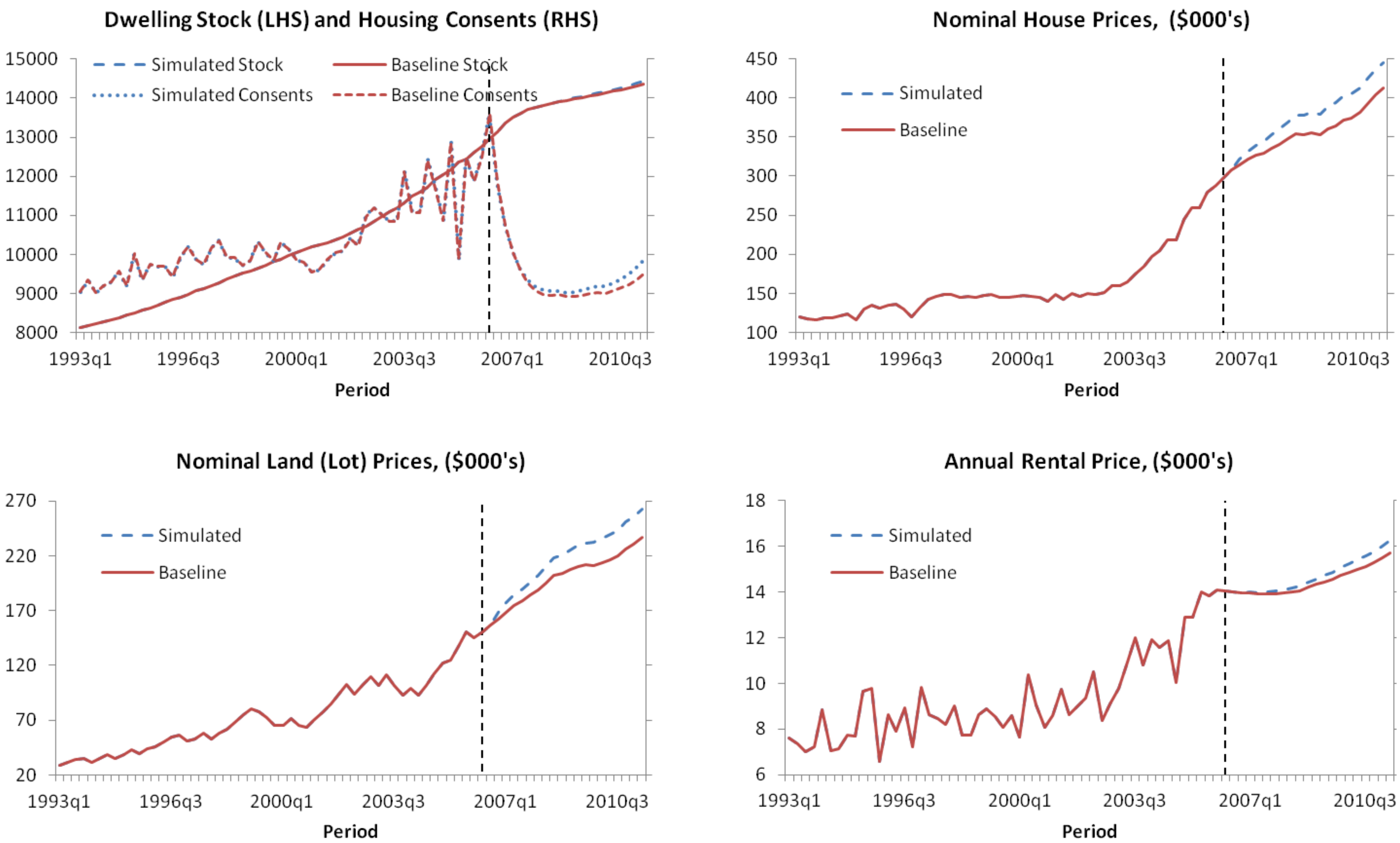


Figure 15: Simulation of Impact of a Christchurch earthquake on Selwyn



7. Conclusions

The New Zealand Regional Housing Model (NZRHM) provides a framework to analyse the impacts of key policy choices and other exogenous influences on housing market outcomes. The model doubles as a potential tool for short to medium term forecasting purposes.

The model focuses upon four key variables within local housing markets: house prices, housing supply (new dwelling consents), residential vacant land (lot) prices, and average rents. Each of these is modelled at the TLA level across 72 TLAs within New Zealand using quarterly data from the early to mid 1990s to 2011Q2. The four modelled (endogenous) variables interact with each other in a system of equations, and are influenced by a range of exogenous influences. Thus one can trace the effects of, say, a change in the rate of development contributions through to lot prices, house prices, rents and new housing supply.

The estimation strategy maintains that each of the four modelled relationships has a long term (equilibrium) component that shows the value to which the modelled variable will tend given the values of the policy and exogenous variables in the system. These values can change as the policy and exogenous variables alter over time. Values of the exogenous variables differ across TLAs and so each TLA – while driven by the same underlying economic forces – will have differing housing market outcomes reflecting their own population and other developments.

In addition to the long-run relationships, the model contains dynamic components that show how each endogenous variable adjusts towards equilibrium. In doing so, recent changes in other variables may impact the dynamic adjustment path, potentially causing some initial movements away from equilibrium. Price expectations, in particular, may cause housing market adjustments that lead to temporary deviations in outcomes away from equilibrium. The inter-relationships within the model are briefly summarised as follows.

House prices in each TLA are determined, in the long run, positively by: population relative to the existing housing stock, the level of accommodation supplement payable to homeowners, and long term income developments. House prices are influenced negatively by the cost and the restrictiveness of credit. Additional short term influences include changes in regional economic activity and changes in average rents (both positively).

In the long run, lot prices are positively determined by farm prices, house prices, development plus financial contributions that are payable to the council, and by population pressures (current population relative to population in 1991). Long run rents are positively determined by: house prices and interest rates (the one year mortgage rate). Rents are influenced negatively by expectations of future house price inflation (proxied by three year rates of past house price inflation) since expected capital gain forms part of the total expected return on a rental property for a landlord. An additional (positive) short term influence is the change in the average rate of accommodation supplement payable to renters.

An equilibrium relationship exists between house prices and the total cost of building a new dwelling comprising both lot prices and construction costs. New dwelling supply (proxied by new housing consents) reacts positively to: the ratio of house prices to total new dwelling costs, and rates of change (over the preceding three years) in house prices and construction costs. New dwelling supply reacts negatively to changes in the restrictiveness of credit.

The value of the model is illustrated by simulating the implications of various shocks to the model for the Manukau TLA, including shocks to exogenous variables (population, credit restrictions, construction costs and farm prices) as well as policy variables (developer contributions per housing consent, accommodation supplement receipts and land availability). We further test the model by simulating consequences of the Christchurch earthquakes, and consider the dynamic effects on the housing markets of Christchurch City and the surrounding TLA's.

An overarching conclusion from these simulations is that shocks cause long-lived dynamics within the housing market. The key reason for these prolonged dynamics is the time that it takes to achieve a material change in the dwelling stock through new construction. For instance, our simulation shows that five years after a 5% population increase in a TLA, the simulated dwelling stock in that TLA will have increased by less than 1%. There are therefore prolonged upward impacts on prices in the model (house prices, lot prices and rents). This feature of the housing market, coupled with the size of shocks that have hit Christchurch, imply that housing market adjustment in that city will extend over many years and cannot be expected to be close to fruition within a five year period after the earthquakes.

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Appendix 1: Data Appendix

A. Raw Data

A.1 Accommodation Supplement Series, AS_t^*

The Department of Building and Housing (DBH) supplied us with Accommodation Supplement (AS) data, obtained from the Ministry of Social Development. This dataset contains the number of AS claimants per quarter at the national level, as well as the total supplement paid to all claimants weekly, and the sum of their declared accommodation costs. This is broken down by tenure type (boarding, living in own home, renting, or un-coded; the boarding and un-coded groups are very small so we focus on the renting and own home groups). The data are not available at TLA level and we could only obtain the quarterly data from 1996Q2 onwards; thus the current dataset contains 64 national-quarterly observations from 1996Q2 to 2012Q1.

A.2 Credit Restrictions Series, CR_t

The Reserve Bank of New Zealand reports a quarterly summary of aggregate financial data for New Zealand registered banks, including the value of non-performing loans (defined as impaired loans plus assets that are at least 90 days past due) relative to the total value of loans (reported in the RBNZ's Table G3). As information on 90 day past due assets are first available in 1996Q1, this marks the beginning of this dataset, which currently extends quarterly to 2011Q4.

A.3 Developer plus Financial Contributions Series, DC_{it}

Following the Local Government Act 2002, councils could pass on the cost of infrastructure associated with new developments to developers, as opposed to ratepayers, through development contributions. (Previously, financial contributions could be required in more restricted circumstances under the Resource Management Act.) The sum of development plus financial contributions is reported by each TLA in their annual financial reports, and is available from SNZ in the time-series tables of the Local Authority Financial Statistics release (data item 12 of Table 1.2). We obtain annual observations from June 1993 to June 2010, for the financial year ending that quarter, for each local authority.

A.4 Farm Sales Data, FSP_t and FS_t

We obtain QVNZ data on national farm sales at quarterly frequency from 1980Q1 to 2011Q3. (Whilst the same data exists at a sub-national level, there are low or zero sales in a number of TLA-quarter observations; thus we focus on the national dataset.) We restrict the focus to farm categories that relate to the ANZ Commodity Price Indices; Meat/Skins/Wool (MSW), Dairy, Forestry, and Horticulture, (whilst seafood and aluminium are also included in the index they represent a low volume of sales). The categories, and the commodity group to which they are related, are detailed in table A1.

Table A1: Commodity Price Components and corresponding QVNZ Sales Categories

MSW	Dairy	Horticulture	Forestry
Total Pastoral	Total Arable Land	Horticulture	Forestry Exotic
Specialist Deer	Total Dairy		Forestry Vacant

Arable is attributed to Dairy owing to a high correlation between international dairy prices and wheat prices. Included in the dataset is the sum of the value of all farm sales for a given category in a quarter, which we denote FSP_t, as well as the total land area, in hectares, of all sales in that category, denoted FS_t.

A.5 Censal Dwelling Counts, $\boldsymbol{H_{it}}$

The only official count of dwellings at a sub-national level occurs through the national census. We obtain the final count of occupied and unoccupied private dwellings for each TLA at the time of the 1991, 1996, 2001 and 2006 censuses from Statistics NZ. We restrict the focus to private dwellings (which includes state owned dwellings).

A.6 Housing Consents, $\boldsymbol{HC_{it}}$

Given the number of dwellings at the local authority level are observed only every 5 years, we require an alternative series to provide the dynamics of housing change for the inter-censal period. Given a new property cannot be built without approval from the local authority we can infer dynamics in housing supply from building consents data. Housing Consents information is compiled by SNZ and contained on Infoshare. We consider only the number of new building consents in the "total residential" category for each TLA and quarter. This is available for all TLAs from 1991Q2 and we obtained data to 2011Q3. The data are not seasonally adjusted. Building consents related to alterations are ignored as they reflect modifications to the existing housing stock.

A.7 Land Value Data, $\boldsymbol{LV_{it}}$

Under the Rating Valuations Act 1998 and the Local Government (Rating) Act 2002 a local district and/or regional council is required to value every property for the purposes of setting rates, with revaluations at least every three years. The capital value of a property can be decomposed into Land and Improvement Values, where the land value component reflects a snapshot of the market on the first day of the quarter in which the properties of the district is valued. This data can be obtained from QVNZ. We make use of the total land value in a TLA, and across the categories detailed in subsection A.4, at the valuation point, and linearly interpolate the category shares of land value between valuation periods. For TLAs that are not revalued in 2011, we hold the relative land value in the categories constant from their last valuation point. A quarterly series is thus prepared for the period 1991Q2-2011Q2.

A.8 One year Mortgage Interest Rate, i_t^m

We obtain the average 1 year mortgage rate amongst new customers, reported on the RBNZ website (RBNZ table B3). The data is available monthly from November 1991 onwards. We choose the rate for the month at the end of each quarter as the quarter's 1-year mortgage interest rate.

A.9 Sub-national Population Levels, N_{it}

As with the stock of housing, an official series of sub-national population levels does not exist to a quarterly frequency. However, SNZ compiles the population final counts for every local authority, and then estimates the inter-censal population level for each local authority at an annual frequency. This series is available on Infoshare from June 1996 onwards whilst Motu had the analogous SNZ data for 1991-1995 in their data library. We linearly interpolate between each annual estimate to generate a quarterly series for the period 1991Q2-2011Q2. Such interpolation ignores any seasonality in net migration and births or deaths, but will accurately reflect trend population.

A.10 Building Cost Index, PB_t

A national housing construction cost index is obtained from 1989Q4 onwards from Infoshare, under the Economic Indicators, and then Capital Goods Price Index tabs. We use the Price Index by Group dataset, and choose the residential buildings cost index, where the pricing is related to the cost of building new dwellings or altering the existing stock. There is no equivalent sub-national series.

A.11 Consumer Price Index, PC_t

We utilise the Consumers Price Index, (CPI, table A3 on the RBNZ website), available quarterly from September 1925. However, we rebase the index to equal 1 in 2011Q2 so that real prices are expressed in constant 2011Q2 dollars. Thus,

$$PC_t = \frac{CPI_t}{CPI_{2011Q2}}$$

A.12 Local House Price Index, PH_{it}

A quarterly house price index, reported nationally and at the local authority level, is available on the QVNZ website. We opt for the "All" category, that includes prices paid for all dwellings, including apartments. We obtain a nominal house price series (expressed in dollars) by multiplying each indexed value by the current "All Dwellings" average sales price for each local council, available via the Residential Sales Summary, and deflated by the index value from the period in which the average sales price is used.

A.13 Local Residential Land (Lot) Sales Price, PL_{it}

From the sub-national QVNZ dataset of property sales we obtain quarterly data on the sales price of vacant residential lots for each TLA in New Zealand, from 1980Q1, currently extending to 2011Q3. Vacant residential sales provide an indicator of the value of land that could be used for the purposes of building a new home. However there are some TLA-quarter observations without any sales of vacant residential lots. The immediate solution is to linearly interpolate between the previous and next sales prices for that TLA-quarter. A larger problem exists when there are only a few sales, in which case the sales price series is likely to exhibit considerable noise due to differing characteristics or location of the vacant lot. After estimating the lot price trend for each TLA-quarter with a number of different algorithms, and comparing across methodologies, we adopt a censored moving average process.

Specifically, we estimate an iterated moving average process for each TLA, requiring that the growth rate in sales price from one period to the next must lie on the interval $\left[-\frac{0.1}{1.1}, 0.1\right]$. The boundaries on the growth rates imply that if the price was \$100 today, it could be no more than \$110 in the next quarter, but the price could get back to \$100 as a lower bound in the subsequent quarter. This approach reflects a prior that it is unreasonable for lot prices to move by more than 40% in a year. The approach removes substantial noise from the underlying series, allowing easier understanding of trend movements. Importantly, censoring the (noisy) growth rate in this way does not impose any long-run deviations of the 'trend' data from the underlying series.

A.14 Stratified Mean Rent Series, R_{it}

Tenancy bonds must be lodged with DBH, now MBIE, whilst it is believed that the bond database covers more than 90% of current tenancies. DBH constructed a quarterly series of average weekly rent for each TLA, stratified by bedroom number, and then derived a weighted average of each group to estimate the average weekly rent series for each TLA. We multiply this series through by 52, to render a quarterly series of average annual rent for each TLA. Reliable data extends from 1993Q1 onwards; prior data exists but may be unreliable due to lack of coverage and so is not used here.

A.15 Regional Economic Activity Index, REA_{it}

The National Bank of New Zealand publishes a quarterly summary of economic trends across broad regions of New Zealand, which is based on official Statistics NZ data as well as some internally estimated components. We use this series as a proxy for local income and consumption trends. Given the series is defined at the regional level, we apply a concordance of TLAs to Regional Councils to obtain a sub-national quarterly series from 1987Q3 onwards. In the cases that a TLA is situated within two Regional Councils we apply the rules described in Table A2 below.

Table A2: TLA to RC Concordance Rules for Ambiguous Concordances

Territorial Local Authority	Defined Regional Council
Franklin	Auckland
Waitomo	Waikato
Taupo	Waikato
Rotorua	Bay of Plenty
Stratford	Taranaki
Rangitikei	Manawatu-Wanganui
Tararua	Manawatu-Wanganui
Waitaki	Otago

B: Data Derivation

B.1 Accommodation Supplement Series, $\boldsymbol{AS_t^*}$

We consider three alternative forms of the Accommodation Supplement data, all at national level. For each of the three measures we consider the series for transfers to renters, and transfers to individuals living in their own home.

Firstly we consider the incidence of AS. We construct a measure of the fraction of households receiving either a renting or ownhome AS:

$$AS_t^{j-Frac} = \frac{N_t^j}{\sum_{i=1}^{N} H_{it}}$$

where $j = \{O, R\}$ denotes the series as either ownhome or renting, , N_t^j is the number of Accommodation Supplement recipients for group j in period t, and $\sum_{i=1}^{N} H_{it}$ is the sum of sub-national dwellings over all districts in period t.

Secondly, for both the "renting" and "ownhome" groups we consider the real transfer per recipient, defined as

$$AS_t^{j-Real} = \frac{AS_t^j / PC_t}{N_t^j}$$

where $j = \{O, R\}$ denotes the series as either ownhome or renting, AS_t^j is the sum of weekly Accommodation Supplements paid out to the j group in period t, PC_t is the rebased Consumer Price Index in period t, and N_t^j is the number of national Accommodation Supplement recipients for group j in period t.

Thirdly, we consider the proportion of accommodation costs met through an AS transfer, defined as:

$$AS_t^{j-Frac} = \frac{AS_t^j}{AC_t^j}$$

where $j = \{O, R\}$ denotes the series as other ownhome or renting, AS_t^j is the sum of weekly Accommodation Supplements paid out to the j group in period t,and AC_t^j is the sum of weekly accommodation costs reported by the j group for period t.

B.2 Developer Contributions per Housing Consent, $\boldsymbol{DC_{it}\_HC_{it}}$

Given the development (and financial) contributions data is aggregated to TLA totals, to consider the impact of variations in the associated charges on the system of housing equations we calculate an average rate of development contributions (plus financial contributions) per housing consent. Development plus financial contributions (DC) will be incurred for all new developments, not just for residential developments, but we do not have information on the rate of DCs paid for residential versus other types of consent. Given an assumption of a constant ratio of residential to total consents, and to keep the data requirements to a minimum, we use residential consents as the denominator for the contributions variable. However, caution needs to be exercised when interpreting policy simulations involving changes to this variable. DC's are reported for the entire financial year by each district and entered in the June quarter period. We assume that the parameters on fees are stable over the financial year. Thus, we define the DC per housing consent as:

$$DC_{it}\_HC_{it} = \frac{DC_{i,t+j}}{\sum_{s=0}^{3} HC_{i,t+j-s}}, where\ j = \begin{cases} 0\ if\ t = June\ quarter \\ 1\ if\ t = March\ quarter \\ 2\ if\ t = December\ quarter \\ 3\ if\ t = September\ quarter \end{cases}$$

where $DC_{i,t+j}$ is the sum of developer (and financial) contributions received by TLA i over the financial year ending period $t + j$, whilst HC_{it} is the number of new Housing Consents. To remove the effects of one-off large commercial developments we censor the series such that the maximum DC per Consent is $35,000; this only affects Manukau and Papakura between 2008Q3-2009Q2.

Because the obtained data ended in June 2010, whilst all other data extends to at least 2011Q2, we extrapolate the final four quarters by holding constant the quarterly developer contribution per housing consent constant over the financial year ending June 2011, thus we obtain a quarterly series from 1990Q1 – 2011Q2, which is populated by zeros before 2002Q3.

B.3 Sub-national TLA Classifications

In some equations of the model we allow for estimates to vary between one of three TLA classifications: rural (where the average proportion of land value attributed to commodity production for a TLA over the entire period exceeds 44%), quasi-rural (where the average proportion of land value attributed to commodity production over the period exceeds 20% but is less than or equal to 44%), or urban (all others), where the proportion of land value attributed to commodity production for a TLA-quarter observation is defined as the sum of land value across all categories summarised in Table A1, relative to the total land value. The remaining land value in a TLA quarter is assigned to an 'other' category.

Table B1 lists all TLAs along with their average proportion of land value attributed to commodity production over the sample period and the corresponding classifications. The boundary weights are partly chosen to place a similar number of the 72 TLAs in each classification; there are 23 urban TLAs, 21 quasi-rural TLA's and 28 rural TLAs. This is balanced by ensuring the classification of each TLA is consistent with a sensible notion of a TLA's primary productive activity.

Table B1: Average TLA land value proportion attributed to commodities

Sub-sample	TLA Name	Land Value Proportion in Commodities	TLA Name	Land Value Proportion in Commodities
Urban	North Shore City	0.0012	Wellington City	0.0015
	Lower Hutt City	0.0017	Auckland City	0.0018
	Christchurch City	0.0106	Tauranga District	0.0114
	Upper Hutt City	0.0117	Nelson City	0.0155
	Porirua City	0.0167	Hamilton City	0.0169
	Waitakere City	0.0221	Palmerston North City	0.0383
	Manukau City	0.0463	Napier City	0.0491
	Kawerau District	0.056	Kapiti Coast District	0.0569
	Invercargill City	0.0579	Papakura District	0.0633
	Thames-Coromandel District	0.0755	Dunedin City	0.0766
	Queenstown-Lakes District	0.0769	Rodney District	0.1341
	New Zealand	0.1593		
Quasi-Rural	Taupo District	0.2045	Whangarei District	0.2088
	Rotorua District	0.2265	Tasman District	0.2428
	Marlborough District	0.2509	Wanganui District	0.2871
	New Plymouth District	0.2889	Grey District	0.2929
	Buller District	0.2942	Kaikoura District	0.2947
	Timaru District	0.3421	Far North District	0.3444
	Masterton District	0.3846	Westland District	0.3864
	Hastings District	0.4014	Western Bay of Plenty District	0.405
	Central Otago District	0.4051	Franklin District	0.4071
	Gisborne District	0.4337	Waimakariri District	0.4348
	Horowhenua District	0.4397		
Rural	Opotiki District	0.4434	Whakatane District	0.472
	Mackenzie District	0.4759	Selwyn District	0.4815
	Waipa District	0.5446	Wairoa District	0.546
	Waitaki District	0.5581	Kaipara District	0.559
	Waikato District	0.5613	Ruapehu District	0.6116
	Hurunui District	0.6201	Ashburton District	0.6249
	Hauraki District	0.6259	South Wairarapa District	0.6302
	Manawatu District	0.6516	Gore District	0.6578
	Carterton District	0.6594	Central Hawke's Bay District	0.7027
	Waitomo District	0.7049	Matamata-Piako District	0.7116
	Southland District	0.718	Clutha District	0.7378

Sub-sample	TLA Name	Land Value Proportion in Commodities	TLA Name	Land Value Proportion in Commodities
	Stratford District	0.7758	South Waikato District	0.783
	Rangitikei District	0.7893	Otorohanga District	0.8007
	Tararua District	0.801	South Taranaki District	0.832
	Waimate District	0.8454		

B.4 Sub-national Dwelling Stock, H_{it}

No official sub-national series of dwellings is available between censal observations; thus we estimate one. The dwelling stock can change between quarters for two reasons; (1) previously existing stock is no longer available, perhaps through destruction or conversion to a commercial property, or (2) new stock is constructed, which will be some proportion of lagged approved building consents. Assuming there exists a lag of two quarters between the issuing of building consents and completion of a new dwelling, we have the following identity for the housing stock:

$$H_{it} = (1 - \delta_{it})H_{i,t-1} + \theta_{it}HC_{i,t-2}$$

where H_{it} is the level of the housing stock in TLA i at period t, δ_{it} is the proportion of the previous quarter's housing stock that is no longer habitable, $HC_{i,t-2}$ is the number of residential building consents issued in TLA i in period $t-2$, and θ_{it} is the fraction of such consents that are successfully converted to housing stock in period t.

Two restrictions are required to estimate this relationship. Firstly, one cannot estimate both a time-area varying destruction and consent conversion rate, so we have to treat one as a constant. We choose to freely estimate the conversion rate. Secondly, given we only observe the dwelling stock at censal points it is necessary to treat the consent-to-dwelling conversion rate as constant for a TLA for the 20 quarters between such observations. Given these restrictions, through recursive substitution we obtain the following system of equations,

$$H_{it} = (1 - \delta)^{20}H_{i,t-20} + \theta_{it}\sum_{s=0}^{19}\delta^{20-s}HC_{i,t-22+s}$$

where $t \in \{1996Q1, 2001Q1, 2006Q1\}$.

Such a system of equations is flexible to differing lengths of time between censal periods (which will be important as the scheduled census for 2011 has been postponed to 2013).

To estimate the equation we use the censal dwelling counts series and the housing consents data, described in Sections A.5 and A.6 respectively. The depreciation/ destruction rate across the entire period for all TLAs is obtained directly from non-linear least squares estimation of the above equation, and is reported in the first row of Table B2. The conversion rate is then estimated by solving each censal period-TLA equation for θ_{it}, i.e.

$$\theta_{it} = \frac{H_{it} - (1-\delta)^{20} H_{i,t-20}}{\sum_{s=0}^{19} (1+\alpha)^{20-s} HC_{i,t-22+s}}$$

The conversion rate is specific to the inter-censal period and the TLA. The estimated average conversion rate for a censal period and a given urban/quasi-rural/rural classification is displayed in the remaining rows of Table B2 below.

Table B2: Dwelling Stock Estimation Results

	Urban	Quasi-Rural	Rural
$\boldsymbol{\delta}$	0.006	0.006	0.006
$\overline{\boldsymbol{\theta}_{1996Q1}}$	0.883	1.160	1.000
$\overline{\boldsymbol{\theta}_{2001Q1}}$	1.081	1.085	0.852
$\overline{\boldsymbol{\theta}_{2006Q1}}$	1.293	1.198	1.074

The majority of conversion rates exceed 1 which may reflect conversion of existing dwellings (and non-dwellings) into multiple dwelling units (via additions and alterations consents). Nevertheless, housing market dynamics will be reflected appropriately through the quarterly consents data, while our use of census snapshots ensures that the dwelling trend is also based on observed data.

Given the 1991 censal dwelling count for each TLA, and the estimated parameters of consent conversion and dwelling destruction, we estimate the dwelling stock for each TLA for every quarter between 1991Q1 and 2006Q1. An issue arises as to how to predict the housing stock in the periods after the latest census. We hold the 2001-2006 conversion rate fixed until the next census occurs in 2013, after which the parameters for this interval should be estimated, and used to update the post 2006Q1 dwelling stock estimates.

B.5 Quarterly Price Growth Series, $\boldsymbol{PB_t^G}$, $\boldsymbol{PC_t^G}$, $\boldsymbol{PH_{it}^G}$, $\boldsymbol{PL_{it}^G}$

We define the extrapolated ("expected") growth rate in prices as the geometric average growth rate in prices over the last three years, or 12 quarters. That is,

$$PB_t^G = \left(\frac{PB_t}{PB_{t-12}}\right)^{\frac{1}{12}} - 1, \qquad PC_t^G = \left(\frac{PC_t}{PC_{t-12}}\right)^{\frac{1}{12}} - 1,$$

$$PH_{it}^{G} = \left(\frac{PH_{it}}{PH_{i,t-12}}\right)^{\frac{1}{12}} - 1, \qquad PL_{it}^{G} = \left(\frac{PL_{it}}{PL_{i,t-12}}\right)^{\frac{1}{12}} - 1$$

B.6 Region Specific Farm Price, $\boldsymbol{PF_{it}}$

We construct a national series for the real average farm sales price per hectare for each of our four commodity classifications based on all property sales across the country , i.e.

$$APF_t^j = \frac{FSP_{jt}}{FLS_{jt}} \; where \; j = \{MSW, DAI, HORT, FOR\}$$

where j is an index for the ANZ component commodity series, FSP_{jt} is the sum of the value of farm sales across the country for activity j in period t, PC_t is the level of the rebased Consumer Price Index in period t, and FLS_{jt} is the total land size in hectares across all farms sold in category j, period t.

A region's representative farm price per hectare is proxied by the weighted sum of each category's average sales price per hectare, where the weights are defined as the proportion of total land value assigned to each specific commodity group (from table A1) relative to the total land value in any commodity production activity for a TLA, such that the weights sum to one. The representative real farm price per hectare in TLA i, period t, is then given by:

$$PF_{it} = \sum\nolimits_{j \in ANZ} \left(\frac{LV_{ijt}}{\sum_{j \in ANZ} LV_{ijt}} . APF_t^j\right)$$

where j is an index for the ANZ component series and LV_{ijt} is the land value attributed to activity j in community i, period t.

B.7 Rental Yield, $\boldsymbol{R_{it}\_PH_{i,t-1}}$

The rate of return to a property investor, realised through the amount of rent received a year, is an important determinant of both the demand for housing and the cost of accommodation. To calculate the rental yield we use the annualised rent series obtained from DBH, now MBIE, and deflate it by the house price index for the given TLA from the previous quarter, as we suggest current prices determine the next years rent, which is analogous to a dividend yield from a general investment i.e.

$$R_{it}\_PH_{i,t-1} = \frac{R_{i,t}}{PH_{i,t-1}}$$

where R_{it} is the annualised stratified mean rent obtained from DBH for TLA i, period t, and $PH_{i,t-1}$ is the house price index in dollars for TLA i, in period $t-1$.

B.8 Real User Cost of Capital, UC_{it}

Most home purchases are largely financed through a mortgage, in which case the direct user cost is the interest paid by the purchaser. (We abstract from tax considerations relating to landlords' purchases; this could be incorporated into future work but would require differentiation between owner-occupier and landlord purchases.) In addition, the expected change in the price of the house, representing an expected capital gain or loss, needs to be incorporated into the user cost term. Accordingly, we define the real user cost of housing as the 1-year mortgage rate less the annual inflation rate, less the real expected capital gain on housing (formed according to the extrapolated price growth series discussed in subsection B.6), all expressed at a quarterly rate, i.e.

$$UC_{it} = \left(\frac{1 + i_t^m}{(PC_t/PC_{t-4})}\right)^{1/4} - \left(\frac{PH_{it-1}^G}{PC_{t-1}^G}\right)$$

where i_t^m is the 1 year mortgage rate in period t, as reported by the RBNZ, PC_t is the level of the rebased consumer price level in period t, and PH_{it-1}^G and PC_{t-1}^G are as defined in section B.6.

Appendix 2: Derivation of Inverse Housing Demand Function (Grimes and Aitken, 2010)

Consider an economy with N_t identical individuals in time t, each of whom derives utility from real non-housing consumption (cx_t) and housing services (θh_t) where h_t is the individual's housing stock and θ is the ratio of the individual's housing services to housing stock.[8] In each period, the individual earns y_t; the individual's real wealth, w_t, can be allocated between h_t and real financial assets (f_t). The prices of the housing stock and non-housing consumption are PH_t and PC_t respectively; their ratio is denoted $g_t = PH_t/PC_t$, and $\dot{g}_t$ is the expected rate of change of g between t and $t+1$. The real after-tax return on f_t is r_t; the real return on h_t equals the real rate of capital gain $(\dot{g}_t)$ less the rate of depreciation (κ) and less the foregone rate of earnings (or the after-tax cost of borrowing), r_t, on the real housing capital ($g_t h_t$). Thus the intertemporal constraint for the state variable, w_t, is given by (1):

$$w_{t+1} = (1 + r_t)(w_t + y_t - cx_t) + (\dot{g}_t - r_t - \kappa) g_t h_t \tag{1}$$

In each period, the individual has a constant relative risk aversion utility function that is separable in non-housing consumption and housing services; thus the individual's value function in t (with ρ being the discount factor) is given by:

$$V_t = \left\{ \left[\frac{cx_t{}^{1-\delta} + (\theta ht)^{1-\delta}}{1-\delta} \right] + \rho V_{t+1}(w_{t+1}) \right\} \tag{2}$$

Taking the ratio of the first order conditions for (2) with respect to cx_t and h_t respectively, yields the optimum ratio of housing stock to consumption for the individual:

$$\frac{h_t}{cx_t} = U \tag{3}$$

where: $UC_t \equiv (r_t - \dot{g}_t + \kappa)/(1 + r_t)$ is the real user cost of capital for housing.

Aggregating (3) over all N individuals and solving for g_t, we obtain:

$$g_t = \theta^{1-\delta} \left(\frac{Nt}{Ht}\right)^{\delta} CX_t^{\delta}\, UC_t^{-1} \tag{4}$$

[8] Lower case letters denote individual-level variables; upper case letters denote the corresponding aggregate variables or variables faced identically by all individuals.

Expressing g_t as PH_t/PC_t, adding regional subscripts to relevant variables, and taking logs yields expression (5) for the equilibrium house price, as in the main body of the paper:

$$\ln\left(\frac{PH_{it}}{PC_t}\right) = (1-\delta)\ln\theta - \delta\ln\left(\frac{H_{it}}{N_{it}}\right) + \delta\ln\left(\frac{Cons_{it}}{N_{it}}\right) - \ln UC_{it} \quad (5)$$

where: $Cons_{it}$ is total non-housing consumption in i at t.

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