HOUSING CONSTRUCTION CYCLES AND INTEREST RATES

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Research Discussion Paper
2004-08

October 2004

Economic Group
Reserve Bank of Australia

The authors are grateful to participants at the 2004 Econometric Society Conference and at an internal Reserve Bank seminar for their helpful comments. Responsibility for any remaining errors rests with the authors. The views expressed in this paper are those of the authors and should not be attributed to the Reserve Bank.

Abstract

Housing investment is one of the most cyclical components of GDP. Much of that cyclicality stems from the sector's sensitivity to interest rates, but it is also possible that construction lags generate intrinsic cyclicality in this sector. Although the housing sector is generally considered to be more interest-sensitive than the economy as a whole, the degree of this sensitivity seems to vary between countries and through time. In this paper, we model the housing markets in Australia, the United States, the United Kingdom and Canada using a structural three-stage least-squares system. We document the variations in the housing sector's cyclicality and sensitivity to movements in interest rates, and attempt to determine the underlying causes of these differences.

JEL Classification Numbers: E22, E32, R21, R31

Keywords: cycles, housing construction, interest rates

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1. Introduction

Housing investment is one of the most cyclical components of output in many industrialised economies, and likewise one of the more interest-sensitive. It is likely that much of the cyclicality derives from the interest sensitivity, but construction lags and resultant sluggish supply might also lead to intrinsically cyclical responses of output to demand shocks. The particular interest sensitivity of housing demand seems to stem partly from frictions in capital markets. Since these can change over time, it is also likely that the interest sensitivity and cyclicality of housing construction can vary through time and across countries.

In this paper, we use econometric techniques to discern whether the observed cyclicality is intrinsic to the construction sector, or a consequence of its interest sensitivity, and to document differences in this interest sensitivity across four English-speaking countries. In doing so, we are effectively doing for quantities what Sutton (2002) did for prices. We then attempt to reconcile these differences based on institutional differences in the housing construction and mortgage finance markets. The goals of the paper are thus similar to those of Aoki, Proudman and Vlieghe (2002) and McCarthy and Peach (2002), who identified changes in the policy transmission mechanism in the United Kingdom and United States associated with financial sector deregulation.

Our focus on institutional factors places this paper within a substantial recent literature on the different macroeconomic effects of housing market developments, particularly in the context of European Monetary Union (Maclennan, Muellbauer and Stephens 1998; Tsatsaronis and Zhu 2004, for example). Our paper extends the analysis in that literature by proposing a new approach to structural modelling of the sector. This allows us to disentangle supply-side from demand-side factors, and in particular, establish the relative importance of *intrinsic* cyclicality caused by sluggish supply, and *extrinsic* cyclicality resulting from demand responses to the interest-rate cycle.

We find a dominant role for *extrinsic* interest-rate cyclicality in explaining the housing cycle. However, there is also some weak evidence of *intrinsic* cyclicality in some of the countries studied, driven by the interaction between sluggish supply and flexible demand. When a demand shock occurs, supply adjusts only gradually, thereby generating a hog-cycle type effect on both prices and quantities supplied. This is partly due to the fact that the change in the housing stock that households demand can be much larger than the feasible flow of new housing supplied in any one period, and partly due to time-to-build constraints on the construction of that new supply. The extent of the sluggishness in supply presumably depends on a range of factors, including the structure of the construction industry, land availability, regulatory policies and other country-specific factors. It is not feasible to reconcile all these supply-side differences with the quantitative cross-country differences in our estimated supply functions. However, they clearly have considerable scope to affect the magnitude of the transmission of movements in interest rates to housing construction.

When comparing the results across countries, we find evidence of significant differences in the (extrinsic) cyclicality of housing investment, even after allowing for the different paths of interest rates experienced in different countries. That is, our structural modelling appears to identify cross-country differences in the direct response of housing demand to movements in interest rates. This is compounded by variations in the income sensitivity of housing demand across countries. Although we do not formally model the response of permanent income to interest rates, it appears that the direct interest-rate effect and the indirect effect via income represent two channels of the transmission mechanism from monetary policy to demand for new and improved housing.

Institutional arrangements in mortgage finance markets clearly matter in determining these different degrees of interest sensitivity and income sensitivity. Although financial deregulation did not appear to alter demand behaviour in Australia, our results confirm McCarthy and Peach's (2002) earlier findings of a structural change in the dynamic behaviour of housing demand following financial market deregulation in the United States. As well as explaining structural breaks in housing market behaviour within a country, institutional factors might help explain the cross-country differences identified in our empirical results. The prevalence of fixed-rate versus variable-rate mortgage finance appears particularly important, which in turn depends on a range of taxation, regulatory and other policies.

2. Housing Investment Cycles in Developed Countries

The key facts we seek to explain are shown in Figures 1 and 2. Housing construction as a share of GDP has a negative relationship with interest rates.[1] Construction prices are positively associated with construction activity, although there is a slight lag between the movement in activity and the change in prices. This lines up with the observations of Topel and Rosen (1988) for earlier US data, that the price-volume relationship is mainly due to shifts in the demand for new housing tracing out a largely unchanged supply curve. In this context, interest rates appear to serve as a demand shifter. A similar picture applies if growth rates are used rather than shares of GDP, or if housing starts are used instead of national accounts measures.

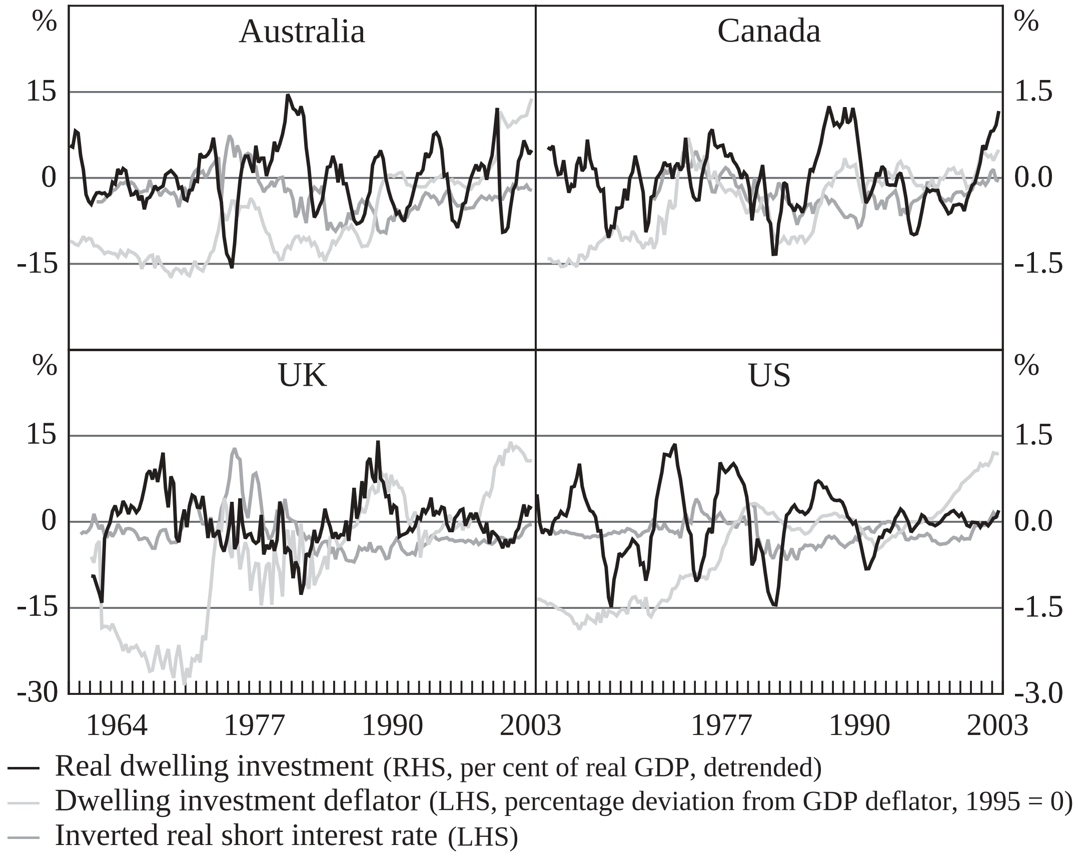
Within these relationships, however, there are clear differences both between countries and across time; these differences are the focus of this paper. In particular, the regularity of the housing cycle in Australia in recent decades is not matched by any of the other countries shown here. The early part of the US data is very cyclical, but as noted by McCarthy and Peach (2002), this pattern has been more muted since the early 1980s. However, this change cannot be wholly attributed to the milder cycle in interest rates more recently.

Although the share of nominal housing construction in nominal GDP for the UK displays some cyclicality, in volume terms the share has been virtually flat for more than a decade. There was a clear cycle in construction in the late 1980s, but this was almost certainly the result of the housing boom occurring at that time, mainly due to factors other than monetary policy and interest rates (Attanasio and Weber 1994; Ortalo-Magné and Rady 1999). The interest sensitivity of the UK housing sector seems to manifest primarily in structure prices, and in the land prices implied by the total price of existing housing.

In New Zealand and Canada, the housing construction share is more variable over time than in the UK or recent US data. It appears that the housing construction

1 Terminology in national data sources can differ substantially. To maintain a consistent set of terminology in this paper, we refer to the dwelling investment component of the national accounts as ‘housing construction’ or ‘dwelling investment’, its associated price deflator as ‘structure prices’, and building commencements as ‘housing starts’. ‘House prices’ denotes the prices including land or location value actually paid by home owners. Figures 1 and 2 show the share of housing construction in GDP detrended using a simple cubic time trend.

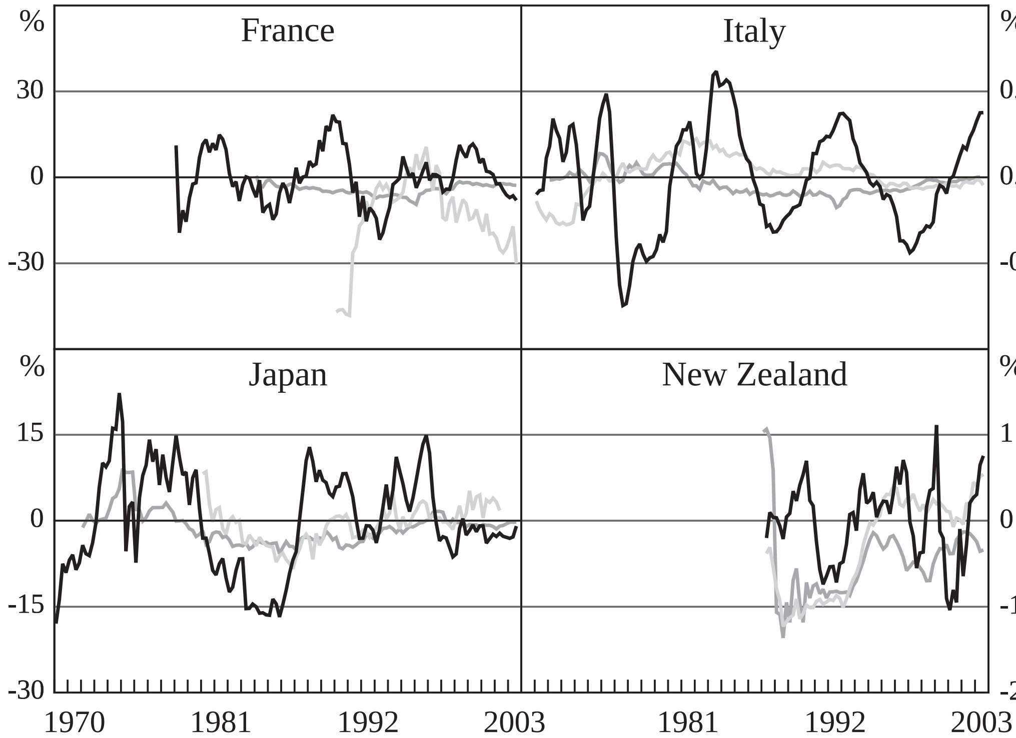
Figure 1: Cyclicality of Dwelling Investment



cycle has similar amplitude to that in Australia, although without the regularity seen in Australia's construction cycle. France, Italy and Japan have all seen substantial downward shifts in the share of housing construction in GDP, as population growth slowed and the post-war reconstruction phase came to a close. Abstracting from this by fitting these data to a cubic trendline, we can discern very mild cyclicality in France and Italy's housing construction share. In Japan, the detrended series displays noticeably more sensitivity to interest rates than the continental European countries, although without the regularity seen in Australia or the early part of the US data.

If the positive price-quantity relationship seen in Figures 1 and 2 captures the shifts of a demand curve tracing out the supply curve, then a regression of housing investment (quantity) on its deflator (price) should estimate the slope of this supply curve. The costs of building – such as labour and materials – would shift the supply curve, but there should not be any additional role for explanators of demand such as interest rates or income. Simple econometric estimates suggest that this is not the case. For all the countries shown in Table 1, non-price factors have a significant

Figure 2: Cyclicality of Dwelling Investment



— Real dwelling investment (RHS, per cent of real GDP, detrended)
— Dwelling investment deflator (LHS, percentage deviation from GDP deflator, 1995 = 0)
— Inverted real short interest rate (LHS)

relationship with housing construction (and housing starts), even after controlling for structure prices in the form of the housing construction deflator. This is consistent with similar results cited in Egebo, Richardson and Lienert (1990). Reduced-form VARs constructed along the lines of those in Aoki *et al* (2002) and McCarthy and Peach (2002) were also consistent with this finding; these results are available from the authors.

In particular, the estimated coefficients on interest rates are negative, and significant for all countries shown except the United Kingdom and Japan. Part of the reason for this could be that interest rates are also a supply shifter, so that the reduced-form estimates are not tracing out an unchanged supply curve. Financing costs are one of the costs of constructing housing, so an increase in interest rates would shift the supply curve left, and reduce quantity supplied. The conclusion of earlier work, however, is that the extent of the estimated relationship between interest rates and construction is too great to be reconciled with financing costs over the duration of a construction project (Topel and Rosen 1988).

Table 1: Coefficient Signs in Reduced-form Models of Dwelling Investment

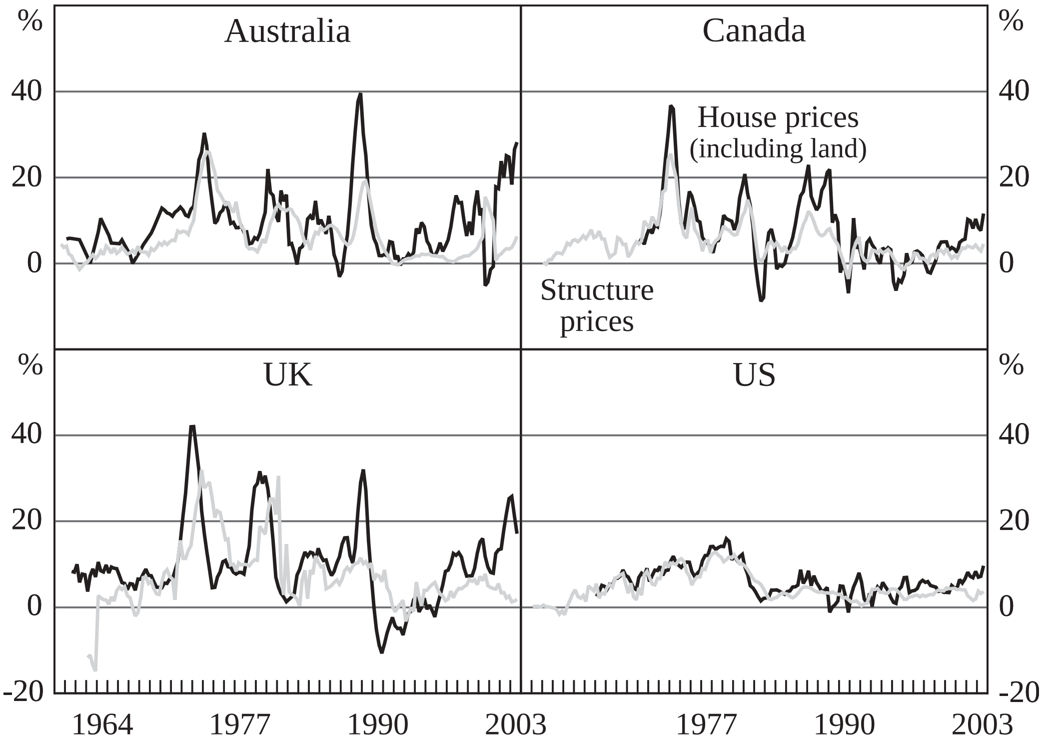
	Simple model		Expanded model			
	Construction costs	Structure prices	Construction costs	Structure prices	Interest rates	Income
Australia	[+]	−	[+]	[−]	[−]	+
Canada	[+]	−	−	−	−	+
France	[−]	[+]	[+]	[+]	[−]	[−]
Japan	[+]	[−]	+	[−]	−	+
Netherlands	[+]	[−]	[+]	+	[−]	[−]
UK	[−]	−	+	+	[−]	[−]
US	−	[+]	[+]	[+]	[−]	[−]

Notes: Plus and minus symbols indicate sign of estimated coefficient. Square brackets indicate that the estimated coefficient is significant at the 10 per cent level. Up to four lags of the dependent variable were also included in both equations.

One initially plausible explanation for housing investment's interest sensitivity – even after controlling for prices – is that suppliers and demanders of housing are not paying the same price. Builders are affected by the cost and sale price of the structure. Home buyers, by contrast, pay the total price of the dwelling, including the cost of the land. As can be seen in Figure 3, the implied price of residential land generally swings around more than the price of the structure, driving significant, usually pro-cyclical, wedges between supply price and demand price. However, many of the causes of this wedge between the two prices, such as zoning laws (Glaeser and Gyourko 2002) and land shortages (Kenny 1999), do not appear to be the main driver of housing cycles. Chinloy (1996) found that cycles in housing construction can exist even when there is plenty of land for development and few zoning restrictions or rent controls to distort the supply decision. In English-speaking countries at least, the greater correlation of interest rates with total housing prices than with structure prices suggests that rates explain much of this pro-cyclical wedge.

Despite the apparent positive relationship between prices and construction visible in Figures 1 and 2, the results in Table 1 force us to conclude that this relationship is not capturing a stable supply function. This implies that a reduced-form estimation strategy is not appropriate. To understand the causes of interest-rate sensitivity in housing construction, we must turn instead to more structural modelling, and try to disentangle demand-side from supply-side influences. In the next section, we develop some variations on existing theoretical models of housing

Figure 3: Cyclicality of House and Structure Prices
Year-ended percentage change



demand and supply, which we then translate into empirical models to be estimated in Section 4.

3. Models of Housing Demand and Supply

In this section, we develop models for supply and demand for both the number of dwellings and the total value of housing construction. This distinction is necessary because, unlike many other goods, production represents an incremental addition to a stock of housing, while demand for housing can be either for the asset, or for the implied flow of services derived from living in a dwelling. In line with previous macroeconomic models of housing construction, we treat the housing market as a national market, even though supply of a new dwelling in one city will not satisfy excess demand in another.

3.1 Theories of Housing Demand

The standard analysis of housing demand recognises that a dwelling is both a provider of a flow of housing services and an asset (Henderson and Ioannides 1986; Ioannides and Rosenthal 1994). Assuming housing services are a normal good, *flow* demand is decreasing in its relative price and increasing in household income. This flow demand is then converted into a desired stock of housing, usually – but not always (e.g., Henderson and Ioannides 1983) – by assuming that services vary proportionately with the stock.

The price of housing services differs from the purchase price: for households that rent, it is simply the rent paid. Households that own their own home incur an imputed user cost, for example as shown in Equation (1). This includes the costs of maintenance and depreciation (δ), plus the opportunity cost of not investing in some other asset with a nominal return of i, partly offset by the expected rate of capital gain or loss on housing $\dot{H}^e$. H is the price per (quality-adjusted) unit of housing.[2] Because there are differences between both the kinds of households that own versus those that rent, and between the kinds of housing they occupy, this user cost is unlikely to arbitrage to measured rents (Ioannides and Rosenthal 1994).

$$\text{User cost} = (i + \delta - \pi - \dot{H}^e) \times H \qquad (1)$$

Asset demand for housing is demand for a stock. Housing can return a flow of actual or imputed rental income R_h, and a capital gain. In the absence of capital-market imperfections or financial regulation, the total (risk-adjusted) return on housing assets should arbitrage to that on other assets, proxied by a real post-tax interest rate in Equation (2) (Meen 1990).

$$R_h + \dot{H} - \delta = (1 - \tau)i(t) - \pi(t) \qquad (2)$$

When households' consumption and asset demands differ, as is possible given the differences between Equations (1) and (2), the discrepancy is resolved by their tenure decision. If the stock equivalent of consumption demand exceeds

[2] If interest payments on mortgage debt are tax-deductible, then the after-tax nominal interest rate $(1 - \tau)i$ replaces the pre-tax rate presented here (Meen 1990, 2000). In Australia, mortgage interest is not deductible; see Bourassa and Hendershott (1992) for discussion of the implications of this. Equation (2) ignores any differences between the capital gains tax treatment of owner-occupied versus investor housing, or across countries.

investment demand, the household rents, while if the reverse is true, it owns its own home and possibly also some investment properties. Some households might also own even if their consumption demand exceeds their unconstrained asset demand. Henderson and Ioannides (1983) argue that an externality exists favouring owner-occupation, because landlords cannot completely extract from tenants the costs of the wear and tear they impose on their home. This externality forces the two demands together. This suggests one reason why housing demand behaviour might vary across countries. If the laws relating to landlord-tenant relations differ, so might the extent of this externality and thus of any deviation between actual demand and predicted consumption demand for housing.

Increases in real interest rates reduce consumption demand for housing through intertemporal substitution and investment demand because the return on alternative assets rises. Distortions in the housing finance market can generate other channels through which interest rates affect demand, in ways that might differ across countries. For example, nominal interest rates can affect housing demand if credit constraints limit the size of the mortgage repayment relative to income (Lessard and Modigliani 1975; Stevens 1997). Downpayment constraints (Stein 1995) and restrictions on the supply of credit (Throop 1986; McCarthy and Peach 2002) might also influence the interest sensitivity of housing demand.

3.2 Modelling Housing Demand

To translate these theoretical models of individual household behaviour into empirical estimates, previous work has generally assumed that the housing stock is fixed in the short run, and placed housing prices on the left-hand side of the equation (Meen 1990). In this paper, we augment that approach by treating the amount of housing demanded by one household separately from the number of dwellings being demanded.

In the long run, the number of new dwellings demanded is proportional to the number of households, assuming a constant vacancy rate. In the short run, the rate of household formation can vary in response to macroeconomic factors such as income (Y), (total) housing prices (P_n), structure prices (P_s) and interest rates (i). The stock of dwellings can also move differently from the number of households, resulting in fluctuations in the vacancy rate (*vac*), calculated as the difference between the (log) housing stock and the (log) number of households.

This naturally leads to an error-correction form for the demand for the (net) number of new dwellings (q in logs), as shown in Equation (3) with lower-case letters denoting log levels except for interest rates.

$$\begin{aligned}\Delta q_t = {} & \alpha_0 - \alpha_1 \left(q_{t-1} + \alpha_2\, vac_{t-1} + \alpha_3\, hhgrowth_{t-1}\right) + \sum_i \alpha_{4i} \Delta q_{t-i} \\ & + \sum_i \alpha_{5i} \Delta p_{h,t-i} + \sum_i \alpha_{6i} \Delta y_{t-i} + \sum_i \alpha_{7i}\, i_{t-i} + \sum_i \alpha_{8i} \Delta p_{s,t-i}\end{aligned} \tag{3}$$

The log change in the number of dwellings represents completions of new dwellings and conversions, less demolitions. However because of data limitations, our empirical models use housing starts instead, which will affect the estimated dynamics' lag structure.

Given this specification for quantity or *flow* demand for new dwellings, an equation for house prices can be motivated as capturing the demand for the quality of the housing *stock* by the representative household. Previous work has not been supportive of a long-run cointegrating relationship between housing prices and fundamentals such as income (Gallin 2003). In contrast, we were able to find a significant long-run relationship between housing prices and a measure of income for Australia and the US, but not the UK or Canada. Where such a relationship could not be found, we assumed instead that the relative price of housing – the difference between the log price of housing p_h and the log general price level p – is constant in the long run.[3] Short-run fluctuations in house prices may then be driven by fluctuations in income, the prices of a house including land (p_h) and of improved housing quality (structure prices p_s) and the price of finance (interest rates), as shown in Equation (4), while the scarcity of housing (the vacancy rate) matters at longer horizons.

$$\begin{aligned}\Delta p_{h,t} = {} & \beta_0 - \beta_1 (p_{h,t-1} - p_{t-1} - \beta_2 y_{t-1} + \beta_3 vac_{t-1}) + \sum_j \beta_{4j} \Delta p_{s,t-j} \\ & + \sum_j \beta_{5j} \Delta p_{h,t-j} + \sum_i \beta_{6j} \Delta y_{t-j} + \sum_j \beta_{7j} i_{t-j}\end{aligned} \tag{4}$$

In principle, both real and nominal interest rates should enter into the estimation; real rates enter into underlying arbitrage conditions, but nominal rates capture the

[3] We impose this restriction by assuming the long-run coefficient on the general price level is equal to that on housing prices, but with the opposite sign. The data do not reject this restriction.

effects of some credit market imperfections. Alternatively, nominal interest rates and inflation could be included, and the difference between the absolute values of the resulting estimated coefficients attributed to the effect of nominal rates independent of that of real rates.[4] We use policy interest rates in all our models for cross-country comparability, even though this is not the mortgage rate that households actually pay.

3.3 Housing Supply

In contrast to the demand side, housing supply is necessarily specified in terms of the flow of new investment. Profit-maximising firms will have a positive supply response to selling prices for structures, and a negative response to their own costs, including interest rates. To maintain the distinction between structure prices and the total price of established dwellings actually paid by households, we require two expressions for supply, as we did with demand – one for number and one for value of dwellings. We assume that producing a structure of a given quality B involves a Cobb-Douglas production function as shown in Equation (5) with labour (n), capital (k) and building materials (m) as inputs.

$$B = n^{\gamma} k^{\kappa} m^{\mu} \tag{5}$$

Each home must be situated on a block of land, which can also be of variable quality l; this could represent the value of more convenient locations. The market price of the land unit is $P_l.l$, but the firm faces adjustment costs ($\lambda > 1$) that increase the marginal cost of obtaining additional blocks of land of the same quality (in the same neighbourhood). The firm's profit function (ϖ) can therefore be written as Equation (6), where Q denotes the number of housing units built, w denotes wages, R the rental on capital (which will depend on the interest rate empirically) and P_m is the price of materials. Structure prices (P_s) and land prices (P_l) are effectively the costs of constructing the home, plus any per-unit mark-up on those costs. If arbitrage is operating properly in the housing market, the structure cost is the difference between the cost of an empty block of land and the price at which the home plus land is sold to the purchasing household

4 This equivalence assumes that (*ex ante*) real interest rates are at least on average equal to the difference between nominal interest rates and the *ex post* rate of inflation.

(Rosenthal 1999). The total price paid for the dwelling by the household is therefore $P_h = P_l l + P_s(n^\gamma k^\kappa m^\mu)$.

$$\varpi = Q\left(P_l\, l + P_s\, n^\gamma\, k^\kappa\, m^\mu\right) - w\,n\,Q - R\,k\,Q - P_m\,m\,Q - P_l\, l\, Q^\lambda \qquad (6)$$

The first-order conditions of this profit function result in the pair of supply functions shown in Equation (7) determining the number of dwelling units produced (Q) and their average quality (B).

$$\begin{aligned} Q &= \left(\frac{l\,P_l\,\lambda}{l\,P_l - m\,P_m + k^\kappa\, m^\mu\, n^\gamma\, P_s - k\,R - n\,w}\right)^{1/(\lambda-1)} \\ B &\equiv \left(P_s\, n^\gamma\, k^\kappa\, m^\mu\right)^* = P_m^{\mu/\beta} P_s^{-1/\beta} R^{\kappa/\beta}\, w^{\gamma/\beta} \end{aligned} \qquad (7)$$

where $\quad \beta \equiv \gamma + \kappa + \mu - 1 < 0 \quad$ assuming decreasing returns to scale.

Total dwelling supply can be derived as the product of quality and quantity, resulting in a flow-supply equation that depends positively on structure prices, negatively on land prices, and negatively on the costs of production (wages, interest rates and materials costs). Assuming the Cobb-Douglas functional form is a reasonable approximation of reality, total dwelling supply can be estimated using a log-linear specification. The number of dwellings can also be modelled using the same first-order condition shown in Equation (7). Alternatively, the condition can be inverted to express structure prices P_s as a positive function of quantity supplied and costs. The presence of adjustment costs in land acquisition is consistent with imperfect competition, so this representation has a natural interpretation as a mark-up equation in an imperfectly competitive industry. We found it performed better empirically than equations with starts on the left-hand side.

4. Empirical Estimates

Egebo *et al* (1990) surveyed earlier literature and macroeconometric models estimating housing construction. Many of these models specified demand as a stock and supply as a flow, while those designed for forecasting tended to include a stock-adjustment component, with less emphasis on fundamental demand factors. Our focus here is on disentangling supply and demand with a view to understanding cross-country differences, rather than on forecasting performance.

4.1 Data

Limitations on data availability confine our econometric modelling to four countries – Australia, Canada, the United States and the United Kingdom. The models of demand and supply developed in the previous section involve two measures of quantity – number and total investment (number times quality) – and two prices: the structure price and the total price including land. For quantities, we use housing starts from building activity surveys and housing construction investment from the national accounts. The deflator for housing construction is used as the measure of structure prices. Total housing prices are represented as median sale prices of established dwellings; these can be obtained from lenders, real estate associations or statistical agencies, depending on the country. The structure price measure captures the cost of a constant volume of construction, but the average or median house price does not generally incorporate an effective quality adjustment. Thus there might be a wedge between these two price measures beyond that caused by land prices, which would introduce a distortion into our econometric results.

Permanent income is proxied by the sum of non-durables and services consumption, except for the UK, where total consumption is used. We used materials and labour costs series specific to the construction industry to capture construction costs, except for Canada where only economy-wide materials price indices were available. We use the policy interest rate, not the mortgage rate, to ensure that we are comparing the effects of the same kinds of shocks to interest rates across countries. This may reduce the models' fit if mortgage rates key off long rates as in the US, or if interest margins have varied over time, as in Australia. On the other hand, it means we do not need to model pass-through of policy rates to mortgage rates separately.

As shown in Equation (3), our preferred theoretical model of demand for the number of dwellings is driven by the number of households in the long run. Our quarterly series for the UK, the US and Canada are interpolations of annual data, while for Australia, we estimate the number of households using an estimated household formation rate and population data. These smoothed data series avoid the effects of short-run endogeneity in the household formation decision.

Demand for and supply of public housing presumably respond to different forces than the market-oriented forces considered here. However, public housing clearly satisfies the flow (consumption) demand of some households. If the share of public housing changes over time, as has been true in the UK (Attanasio and Weber 1994), time-series estimates for demand for privately owned housing would be distorted by the exclusion of public housing. Thus it would be preferable to consider all dwellings in our estimates, accounting for the differing influences of the public and private sectors. However, because of data constraints in the other three countries, we are only able to include public dwelling construction in the UK, though it is arguably most important there. Further details on the data are contained in Appendix A.

4.2 Preferred Specification

We have four endogenous variables – two different prices, plus quantity and quality of new housing – and four equations determining them in the form of supply and demand equations for both quantity and quality. Many of the explanators are clearly endogenous and likely to be correlated with the equations' error terms.[5] The error terms are likely to be correlated across equations as well, given the tight relationship between variables such as housing starts (quantity) and dwelling investment (quantity multiplied by quality). Therefore we used the three-stage least squares instrumental variables estimator to avoid statistical problems involved with using endogenous explanators. All current-dated variables are treated as potentially endogenous, while all lag-dated variables are taken to be potential instruments. We followed a general-to-specific methodology to arrive at a preferred dynamic specification, but by default we retained variables as instruments that had been dropped from the second-stage estimates of the behavioural equations. This helped avoid serial correlation in the residuals, which would have resulted in inconsistent parameter estimates. Serial correlation would have been especially problematic in an instrumental variables estimate, because the lagged variables used as instruments would also be correlated with the errors.

[5] A version of the model including an equation for construction costs in the model did not materially change the results.

To obtain sensible results, we also made several modifications to the specifications set out in Section 3. As highlighted earlier, we imposed the restriction, in Equation (4) for house prices, that the coefficients on the lagged house price and the general price level be of equal and opposite sign. In the short-run dynamics, we allowed some departure from this by including house price inflation and CPI inflation separately. For Canada and the UK, the *relative* price of housing is the only long-run determinant of house prices. For Australia, the aggregate level of income is also important in the long run, while in the US, average household income matters.[6] Similarly, we allowed for incomplete short-run arbitrage between house-and-land packages and empty blocks of land by including the total price of housing in the structure price equation. This was an important modification; it seems that builders/developers do have scope to set total prices, as in all cases structure prices depend positively on house (and thus implicitly land) prices.

Following Tsatsaronis and Zhu (2004), we also allowed for mortgage tilt and other financial frictions to affect housing demand by including nominal interest rates as an explanator. Because the inflation rate is already in the short-run dynamics to capture the effects of relative housing prices discussed above, including both nominal and real interest rates directly would introduce excessive collinearity. Therefore we included nominal rates on their own and allowed the coefficient on inflation to mop up both the effect of real interest rates and of relative house price inflation. The risk in this approach is that the coefficient on inflation might also be picking up trends that the cointegrating relationships are not adequately capturing; in some cases these were quite imprecisely estimated. Nominal interest rates fell substantially in the countries studied, in line with the disinflations of the 1980s and early 1990s.

Finally, we allowed for structural change, mainly in the short-run dynamics of the models, to capture the effects of financial deregulation, and of the introduction of Goods and Services Taxes (GST) in Australia and Canada. In line with the results in Aoki *et al* (2002) and McCarthy and Peach (2002), we find significant structural instability in the United States and the United Kingdom. In both countries, Chow tests suggest there is a break around the beginning of 1986, consistent with the

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6 This specification of income was extended to the short-run dynamic terms for consistency.

timing of financial deregulation.[7] Although there was some weak evidence of structural instability in the Australian model, we found that the model fit the data better without it. There was no evidence of structural instability in the model for Canada. This is consistent with the lack of a clear episode of financial deregulation in the sample period, since the mortgage market in Canada was already quite lightly regulated as early as the 1960s (Edey and Hviding 1995).

The introduction of a GST permanently shifts the level of structure prices. This is captured as a permanent shift dummy in the post-introduction period, although the effect was not significant for Canada. We also included a dummy in the quarter of introduction to account for the one-off increase in the growth rate of prices. Prices were higher and production lower after the GST's introduction in both countries. We also found evidence of a significant 'bring-forward' effect in Australia – but not Canada – in the quarters immediately preceding the GST's introduction. Demand was temporarily higher as households brought their construction plans ahead of the GST's start date. Supply was also temporarily higher to take advantage of this temporary surge in demand; for example, construction firms were observed to be working unusually high levels of overtime in the period prior to the GST's introduction in Australia.

4.3 Results

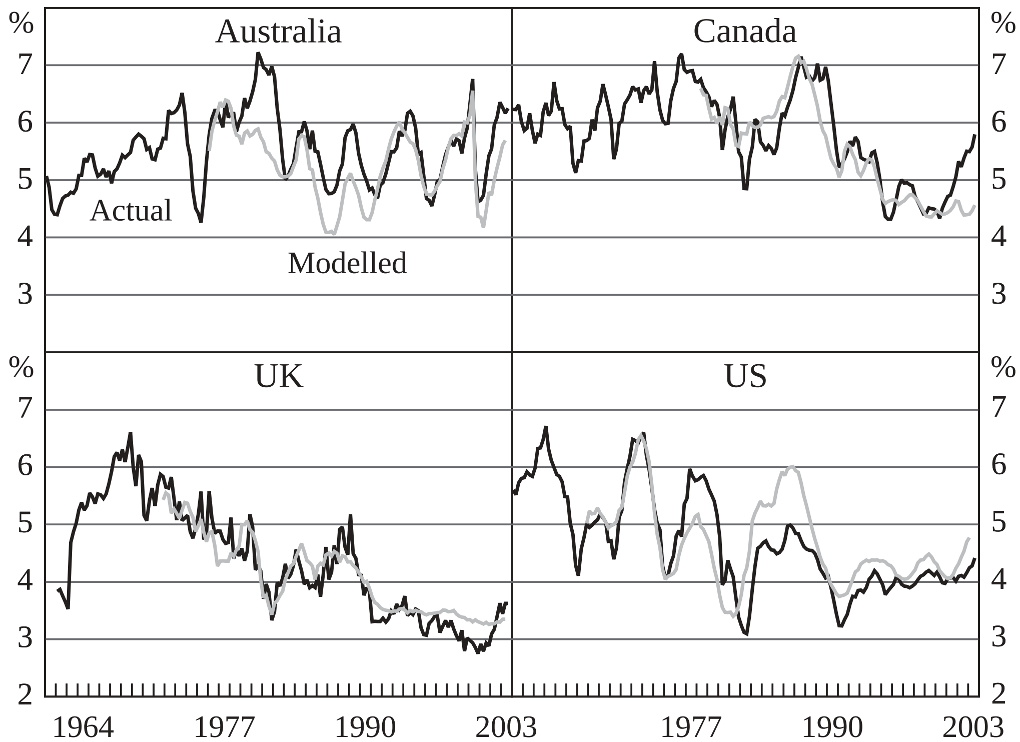
The models presented in Appendix B match the data reasonably well, but plots indicate that the fitted values for housing construction tend to undershoot the actual series for Australia, Canada and the UK in the last couple of years in the sample (Figure 4). It seems likely that some other omitted factor affected outcomes over this period; it may be that households have been spending on housing out of transitory as well as permanent income. Another possibility is that the different treatment of changes in average housing quality in the two price series is hampering separate identification of supply and demand. In any case, the (demand) equation for house prices is not particularly precisely estimated for any of the countries, although in this respect our results compare fairly well with previous

[7] Although statistical tests exist for dating structural breaks in multivariate data (Andrews 1993; Bai, Lumsdaine and Stock 1998), we are not aware of any work on the properties of these tests in an instrumental variables framework.

literature. Some models of housing prices alone (Bourassa and Hendershott 1995; Abraham and Hendershott 1996, for example) incorporate 'bubble' components, implying extrapolative expectations, to account for movements in housing prices that cannot be explained by macroeconomic fundamentals. It may be that our models are not properly capturing such a phenomenon, even though the equations for housing prices already include lagged price growth terms as explanators.

Figure 4: Dwelling Investment

Per cent of GDP

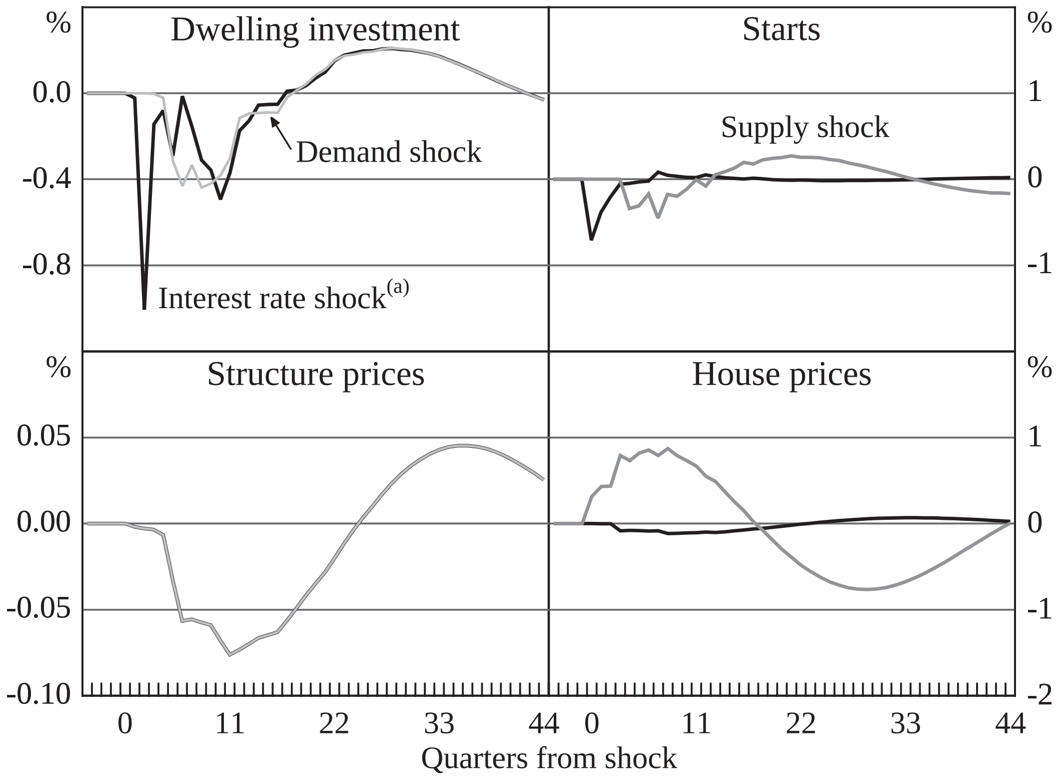


It is difficult to infer much about the behaviour of the housing sector from the raw econometric results, so we explore them using impulse responses. First, we investigate own-price elasticities by subjecting the supply equations to a demand shock (grey lines in the left-hand panels of Figures 5 to 10) and the demand equations to a supply shock (grey lines in the right-hand panels). The resulting responses are analogous to slopes of supply and demand curves, although the dynamic nature of the equations implies that they are not direct representations of either short-run or long-run elasticities. If the demand shock engenders oscillations in supply, we can furthermore diagnose the presence of intrinsic cyclicality.

Next, we explore the interest sensitivity of the sector by tracing out the effects of a 1 percentage point shock to the policy interest rate (black lines in each panel of Figures 5 to 10). Since an increase in interest rates shifts both the demand and supply schedules left, these dynamic responses confound slopes and shifts in the notional curves implied by the econometric results. To ensure some comparability between the two sets of impulse responses, we have calibrated the supply and demand shocks to be the same as the direct effects of a 1 percentage point shock to the policy rate on supply and demand respectively.[8] All results are presented as the log deviation from baseline, scaled up by a factor of 100; this can be interpreted as a percentage deviation from baseline.

Figure 5: US Impulse Response Functions

Pre-deregulation, log deviation from baseline



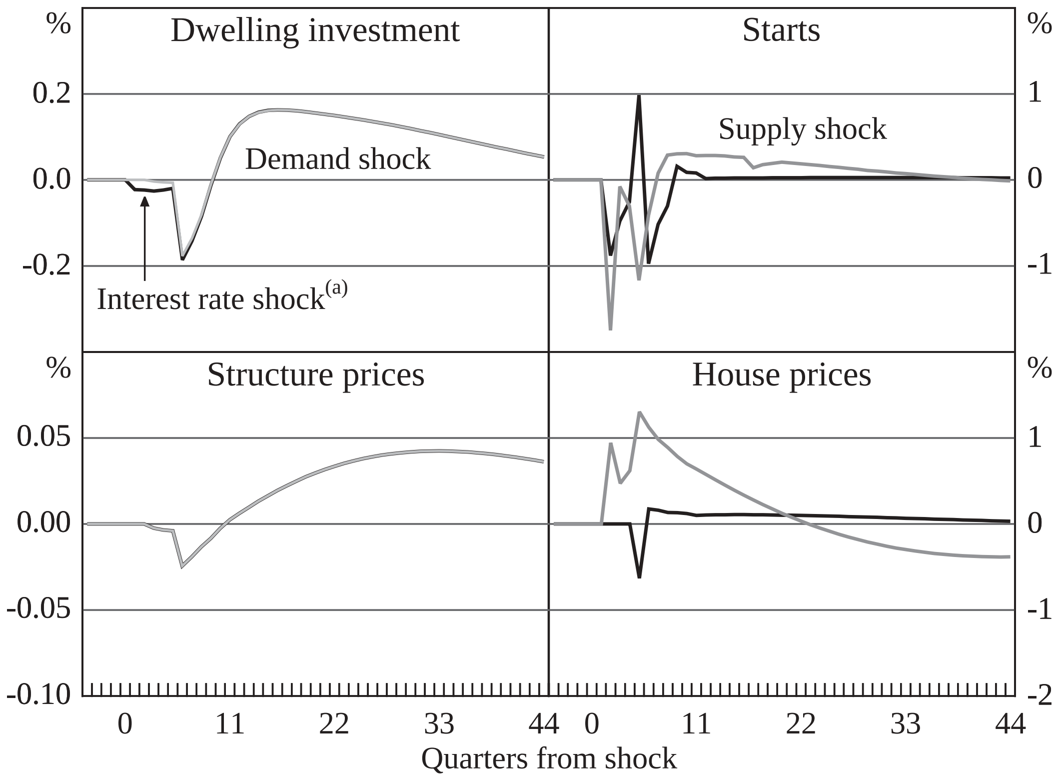
Note: (a) Response to a 1 percentage point shock.

8 That is, the shock is calibrated so that the direct, short-run effects are the same as for the interest rate shock. In the UK and the US, we shocked structure prices by 1 per cent even though interest rates did not enter that equation.

In the case of the US (Figures 5 and 6), there is no distinction between a demand shock and an interest rate shock, since in the preferred specification, interest rates only enter into the demand-side equations. That said, the results imply that supply is more price-elastic than demand. The quantity response to a contractionary demand shock or interest rate shock is greater than the apparent price response. In contrast, a contractionary supply shock results in a shift in demand that mainly changes prices rather than quantities. The effect of an interest rate shock is accordingly concentrated in quantities rather than prices, especially in the post-deregulation period. In line with the findings of McCarthy and Peach (2002), our results suggest that the housing demand in the US became less interest-sensitive following the deregulation of the financial sector.

Figure 6: US Impulse Response Functions

Post-deregulation, log deviation from baseline

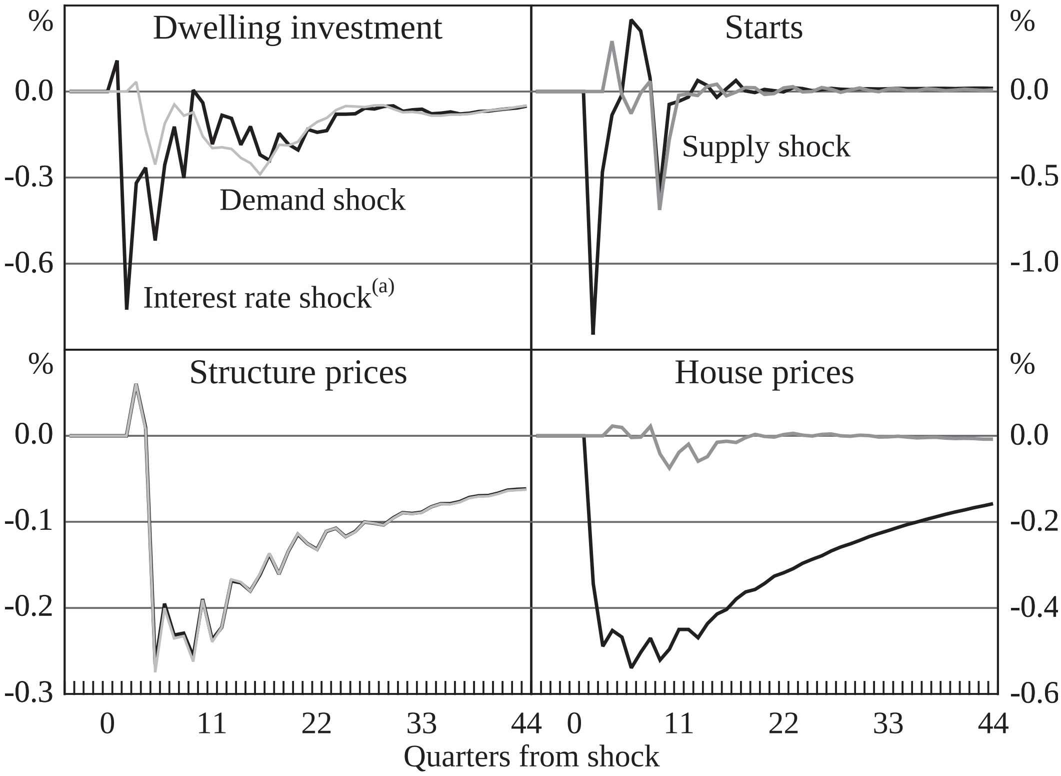


Note: (a) Response to a 1 percentage point shock.

In contrast, the results for the UK are consistent with demand being more price-elastic than supply. Figures 7 and 8 show that a demand shock traces out a much greater price effect relative to the quantity effect on supply than is the case for the effect of a supply shock on demand. Although confounded by the inclusion of public housing construction, this implies that the notional supply curve is relatively steep, especially in the pre-deregulation period, which is consistent with the overall pattern of housing construction moving relatively little over the course of the cycle. It is therefore not surprising that both the price and quantity effects of an interest rate shock are quite large relative to the results for the US.

Figure 7: UK Impulse Response Functions

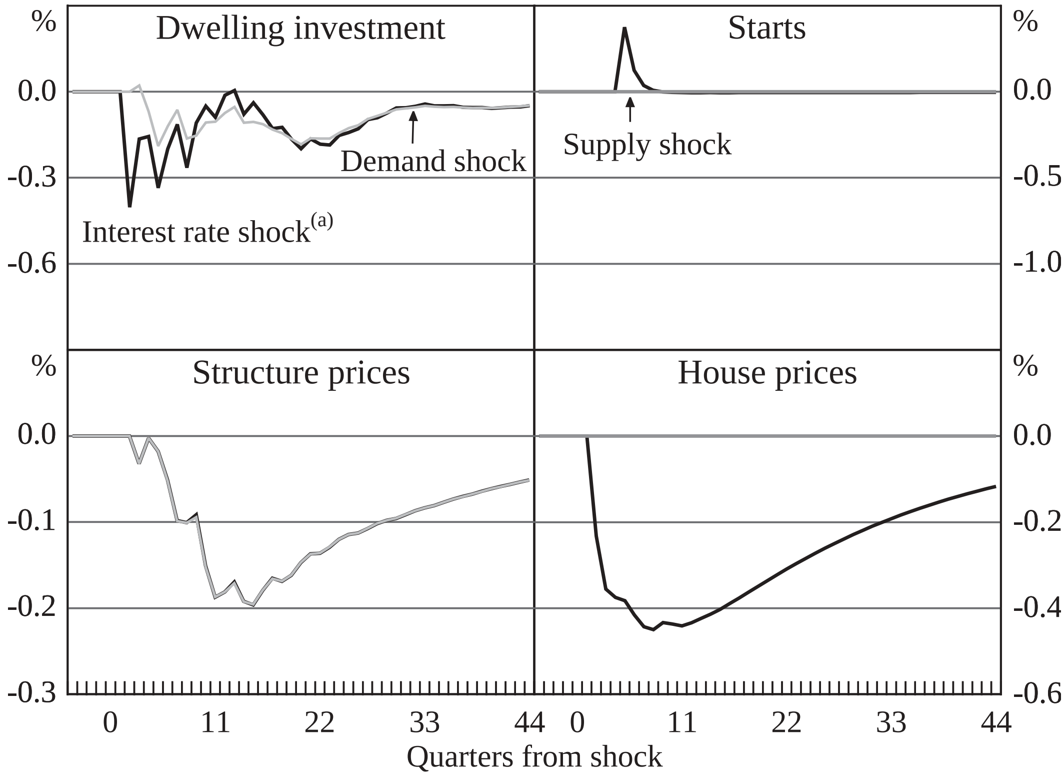
Pre-deregulation, log deviation from baseline



Note: (a) Response to a 1 percentage point shock.

Figure 8: UK Impulse Response Functions

Post-deregulation, log deviation from baseline

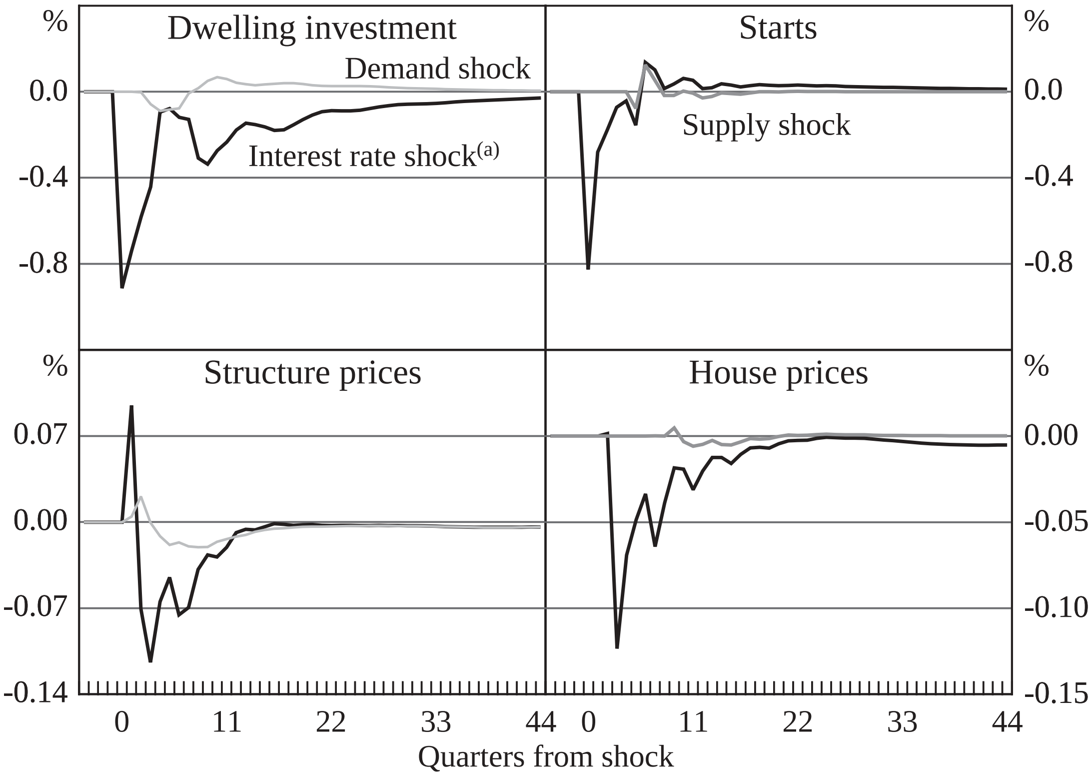


Note: (a) Response to a 1 percentage point shock.

The results for Canada (Figure 9) are also consistent with a relatively flat (price-elastic) notional demand curve that shifts substantially in response to an interest rate shock. Unlike the UK, however, the total response to a change in interest rates is dominated by a quantity adjustment rather than a price adjustment. That is, the housing sector as a whole is more elastic in the face of shocks than its UK counterpart. Indeed, of the four countries studied here, only in Canada does the effect of a move in interest rates weigh more heavily on structure prices (p_s) than on the total price of established housing including land (p_h). The implied response of land prices must therefore be relatively subdued, which suggests that land availability is less of a constraint on housing construction in Canada than in the other countries studied here. This ties in with other evidence suggesting that the *level* of housing prices is relatively low in Canada (Ellis and Andrews 2001). One reason for this might be that a greater proportion of the Canadian population lives in middle-sized cities where congestion costs are limited. This greater availability of land might contribute to the relatively elastic response of quantity supplied.

Figure 9: Canada Impulse Response Functions

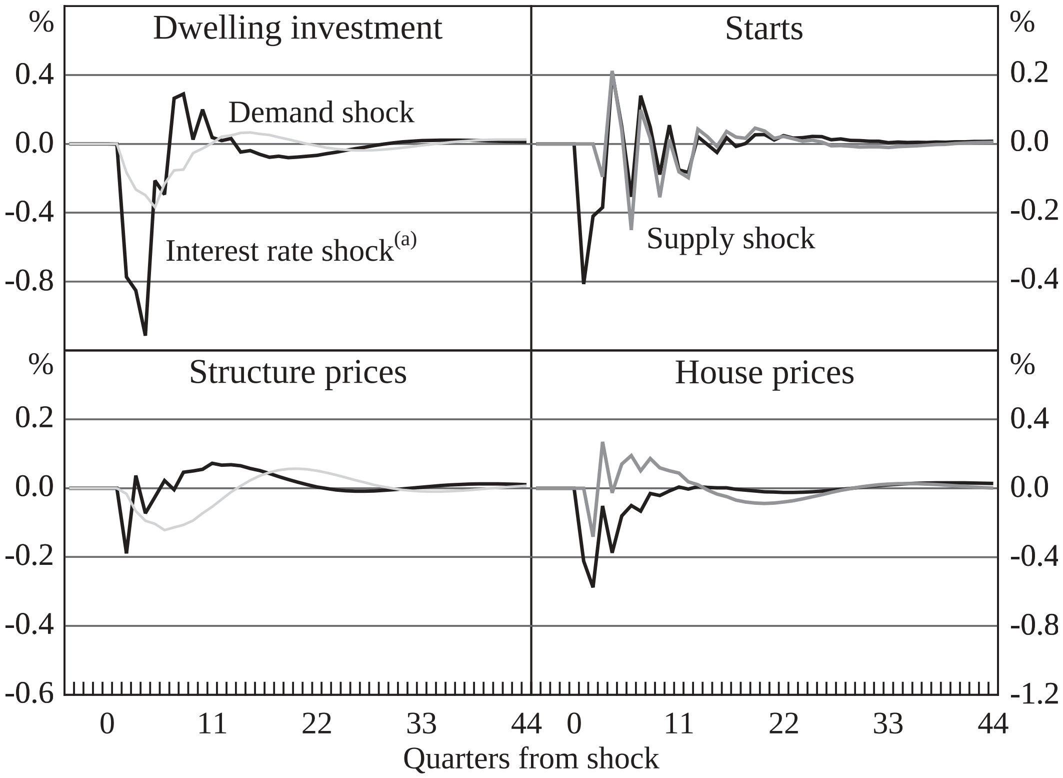
Log deviation from baseline



Note: (a) Response to a 1 percentage point shock.

Finally, Figure 10 shows that only the Australian housing sector displays significant intrinsic cyclicality, as evidenced by the oscillations in quantity supplied following a demand shock. Only the pre-deregulation period for the US shows similar behaviour, and not to the same extent. Looking beyond this cyclicality, it appears that both supply and demand in Australia are quite elastic, with the ratio of the price response to quantity response being comparable to the US on the demand side, and Canada on the supply side. Similarly, the combined effect of a shock to interest rates on dwelling investment and house prices is the largest of the four countries studied.

Figure 10: Australia Impulse Response Functions
Log deviation from baseline



Note: (a) Response to a 1 percentage point shock.

5. Discussion of Results

The responsiveness of demand-side variables to changes in interest rates lines up reasonably well with what would be expected from differences in mortgage finance institutions in these countries, as summarised in the first column of Table 2 for these four and a selection of other industrialised countries. As previously emphasised by Maclennan *et al* (1998) in the European context, the structure of the mortgage finance industry largely determines the speed of transmission of changes in interest rates to mortgage borrowing behaviour. Australia and the UK, where mortgages are predominantly offered at variable rates, display more overall interest sensitivity than does the US, where an array of institutional arrangements have been designed to support the existence of a long-term fixed-rate mortage market. Similarly, in the early period of regulated financial markets, housing demand in the US and UK was more interest-sensitive than more recently. This tends to confirm the findings of McCarthy and Peach (2002); that financial regulations affecting the supply side of the mortgage market resulted in the demand side of the housing market being more interest-sensitive than if those lending restrictions had not been in place. In Canada, five-year fixed-rate mortgages predominate, consistent with its intermediate degree of responsiveness to interest rates.

Another aspect of the mortgage market that may be relevant to a reconciliation of demand-side behaviour is the tax treatment of mortgage interest. In the consumption and asset demands framework outlined in Section 3.2, non-deductibility of mortgage interest implies that movements in interest rates have full force on user cost and the arbitrage conditions determining individuals' demand, Equations (1) and (2). Therefore it should be expected that housing markets in countries where mortgage interest is not deductible for owner-occupiers should experience larger effects of movements in interest rates. If this is true, then the recent completion of the abolition of mortgage interest deductibility in the UK should be expected to result in a shift in demand behaviour to become more interest-sensitive than is presently the case.

Table 2: Housing Finance Institutions and Selected Demographic Indicators

Country	Predominant mortgage type	Typical mortgage term (years)	Average annual population growth (1980–1998)	Population density (2001)
Australia	Adjustable	25	1.4	2.5
Canada	Five-year fixed	25	1.2	3.3
US	Full-term fixed	30	1.0	30.8
NZ	Adjustable	25	1.1	14.3
France	Five-year fixed	15	0.5	107.1
Germany	Adjustable	10	0.3	230.5
Netherlands	Adjustable	30	0.6	469.9
UK	Adjustable	25	0.3	243.8
Japan	Adjustable	30	0.4	348.1

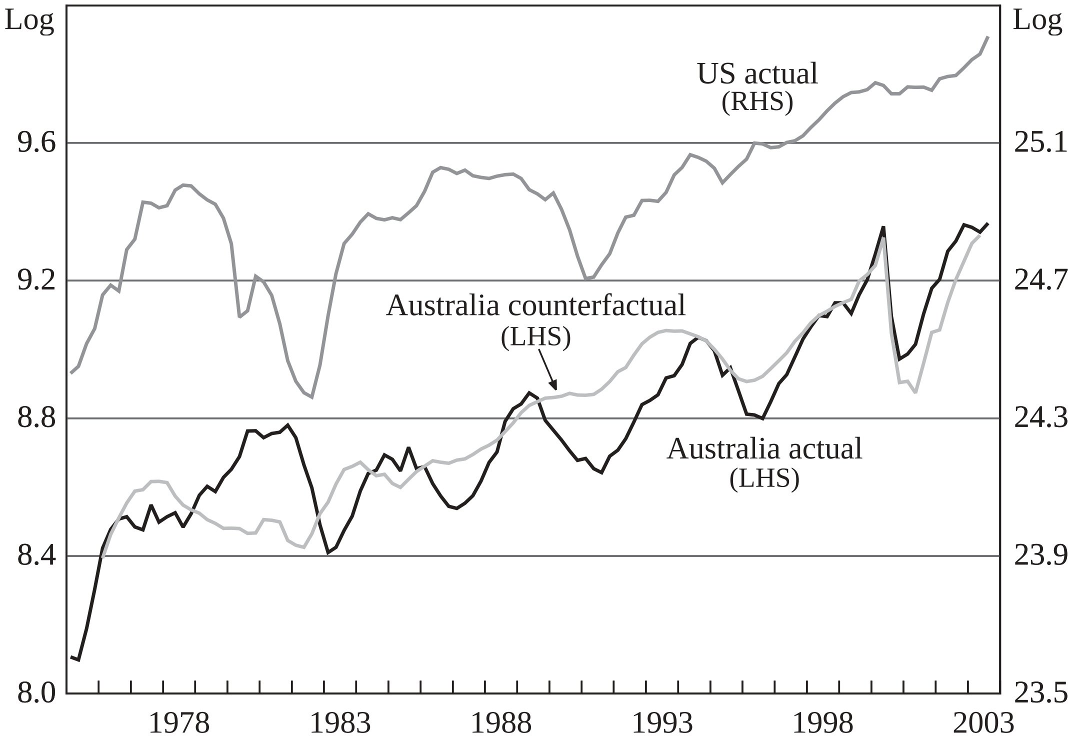
Note: All variable, negotiable and reviewable interest rates are treated as adjustable.
Sources: mortgage market characteristics – BIS (2003); demographic characteristics – World Bank

The patterns of interest sensitivity do not, however, completely line up with the differences in amplitudes of housing construction cycles identified in Section 2. Moreover, within this overall pattern of interest sensitivity, there are other clear differences, such as in the split between price and quantity responses. If the mortgage characteristics were the only consideration, the responses of Australia and the UK would be much more similar than they are. Two factors suggest themselves as likely additional considerations in a reconciliation of these cross-country differences evident in Figures 1 and 2. Firstly, even economies with otherwise identical structures will experience different housing cycles if they face different paths of interest rates, perhaps brought about for reasons other than developments in the housing sector. And secondly, the split of the total response between quantities and prices depends on the price elasticities of both demand and supply, as well as on the extent to which demand shifts in response to a change in interest rates.

As an illustration of this first point, we can use the models estimated in this paper to construct a counterfactual outcome for Australia that would have occurred had the United States' path of interest rates prevailed instead. This counterfactual series, shown in Figure 11 along with the actual series for both countries, is calculated by replacing the actual Australian interest rate series with the US equivalent, and generating the fitted values that would have resulted, given our estimated coefficients. Obviously this results in the *level* of housing investment being higher than the actual outcome, since nominal interest rates were lower in the US than in Australia for much of the period shown; we have not adjusted for the fact that inflation was lower in the US than Australia in the 1980s. The counterfactual series is also smoother than the actual series for Australia, particularly for the 1980s, although still containing more obvious cycles in the 1990s than the actual US series.

This exercise does not correspond to a true counterfactual: at the very least, income also responds to interest rates, and so the path of Australian income entering into housing demand should also have been changed to fit the US interest rate series. This may reduce the cyclicality of the counterfactual Australian series further, since our econometric results also showed that the Australian housing sector was relatively *income*-sensitive. However, this would have required a structural model of income that is beyond the scope of this paper. Even so, it is apparent from Figure 11 that a significant part of the visual impression of regularity in the housing construction cycle in Australia can be attributed to the greater cyclicality of interest rates in the 1980s; the amplitude of the cycle around 2000 is more a result of the introduction of the GST than changes in interest rates. This raises the possibility that, absent further changes to the tax system or other shocks, Australian housing construction cycles might be more muted in the future than was the case historically.

Figure 11: Actual and Counterfactual Housing Construction



A more extensive illustration of the role of different paths of interest rates can be obtained by eliminating interest rates from the model entirely. Table 3 shows the changes in the variances of the endogenous variables that would ensue from holding interest rates constant at their sample means, given the estimated parameters and the paths of the other exogenous variables. For each country, the variances of the actual fitted values for the two quantity variables are greater than the variances of the counterfactual series where rates are held constant. This demonstrates that interest rates have an important role in explaining construction cycles: in particular, they appear to explain more of the variation in dwelling investment in Australia than in the US or UK, while housing starts are most interest-sensitive in the US. These results also imply that movements in interest rates have little exogenous effect on the variances of prices of housing and structures.

It is also apparent from Table 3 that cross-country differences in housing outcomes persist even when the influences of the path of rates, and consequently the differences in interest sensitivity, are removed. Because Table 3 compares variances of fitted values, these remaining cross-country differences are not due to the contemporaneous effects of different shocks. They may partly relate to the differences in the strength of the indirect influences of rates via the income channel, which as mentioned earlier, have not been removed in these results, as well as variation in other exogenous variables. However, it is also likely that some part of the cross-country differences can be attributed to different dynamic responses of the endogenous variables once a shock has already occurred.

Table 3: Variance of Predicted and Counterfactual Endogenous Variables

Equation	**Australia**		**Canada**		**UK**		**US**	
(change in...)	Fitted	Counter-factual	Fitted	Counter-factual	Fitted	Counter-factual	Fitted	Counter-factual
Dwelling investment	0.194	0.122	0.050	0.038	0.092	0.083	0.113	0.096
Starts	0.438	0.390	0.393	0.359	0.394	0.357	0.215	0.138
Structure prices	0.016	0.013	0.009	0.010	0.031	0.037	0.004	0.005
House prices	0.070	0.056	0.029	0.032	0.045	0.048	0.007	0.010

Notes: Interest rates are held constant at their mean rate in the counterfactual. All variances have been multiplied by 100 to be expressed in percentage points.

This underlines the importance of the second factor mentioned earlier – the role of differences in price elasticities. This can be seen by comparing this paper's results for the UK and Australia. In both countries, housing demand is quite interest-sensitive, as well as being quite price-elastic. However, as shown in Figure 1, housing construction is almost completely acyclical in the UK, in contrast to the clear cycles seen in the Australian data, and the impulse response of quantities to interest rate shocks shown in Figures 7 and 8 is likewise much smaller than in either Australia or the US. What appears to be happening is that in the UK, transmission of changes in interest rates to credit markets is similar to that in Australia, but the onward transmission from that market is via housing *prices* to other aspects of consumer behaviour, rather than directly to physical investment in housing. This suggests the presence of a steep supply curve, or some rigidity causing the adjustment in the UK to come through price rather than quantity. This is confirmed by the impulse response analysis: as mentioned in Section 4, the econometric results imply that the notional supply curve is quite steep.

The last two columns in Table 2 provide a hint of the underlying reason for this inelasticity in supply. The UK – and indeed most of continental Europe – is characterised by slow population growth and high population density, in contrast to the situation in Australia, Canada and the US. A given-sized cyclical shift in demand represents a proportionately larger shift compared to the lower average levels of construction activity that might be expected in a country with low population growth. This might entail greater costs of adjustment than if the shift in production was only small relative to the size of the industry. In other words, adjustment costs might provide reasons for construction supply curves to be fairly steep in countries where construction is small relative to its importance in other countries. Given the likely constraints imposed by population density and thus land scarcity, the preponderance of price adjustment rather than quantity adjustment in the UK seems entirely consistent with the characteristics of that market. If countries in continental Europe with a similar supply environment had mortgage markets like that of the UK, one might also expect them to experience similar variability in housing prices.

Another possible contributor to the greater amplitude of housing construction cycles in Australia may be the apparent intrinsic cyclicality identified in the impulse response analysis for Australia, but not elsewhere. Since some of the estimated parameters in these models are imprecisely estimated, it would be a mistake to make much of the finding that only Australia's housing sector exhibits intrinsic cyclicality in the face of a simple demand shock. This finding could, however, be another factor explaining the differences shown in Figures 1 and 2. It is also important to note that intrinsic cyclicality does not imply that supply is inelastic. Rather, intrinsic cyclicality is likely to occur when both demand and supply are quite elastic, but supply is sluggish; that is, the short-run elasticity is much lower than the supply elasticity in the medium to long run. By comparison, the sticky supply evident in the results for the UK imply that construction does not respond much to a shock over any horizon. In that case, there is not enough variation in quantity for an intrinsic cycle to get started.

Although mortgage finance conventions are not the only factors driving differences in the interest sensitivity of housing construction, they have an important role. This naturally raises the question of why the deregulated outcomes for *finance* differ so much. Presumably households in all four countries would value the reduced volatility of payments inherent in a fully fixed-rate loan contract, but only in the US do a significant proportion of households pay for this reduced volatility. A full investigation of the reasons for this difference is beyond the scope of this paper. However, one of the key contributors to this difference appears to be the substantial involvement of government-sponsored agencies in the US mortgage market. The financing advantages of these institutions reduce the term premium that US households must pay for a fixed-rate loan over a variable-rate loan over the whole term. Additionally, the differences in tax treatment mentioned earlier may also be relevant. The incentive to pay off their mortgage ahead of schedule is much stronger in a country where home mortgage interest is not tax-deductible, such as Australia, since alternative uses of funds earn a post-tax, not pre-tax, return. This makes variable-rate loans relatively more attractive, since unlike fixed-rate loans, they do not generally involve penalties for early repayment.

6. Conclusion

In this paper, we have estimated structural models of housing supply and demand for several countries. The separate treatment of number and quality of dwellings has allowed us a reasonable identification of the two sides of the market, and pointed towards some possible reasons for differences between the behaviour of the housing markets in these countries. With only four countries in our data set, it is not possible to demonstrate conclusively that these cross-country differences are the results of the institutional and other differences discussed in the previous section, but they are likely to be important parts of the story.

In particular, the results for the UK seem to indicate that countries with supply constraints on land and generally slow population growth might have housing construction cycles with lower amplitude than those in countries where population growth is relatively higher and where there is more scope to expand residential development. If housing demand displayed similar interest sensitivity in all countries, we should expect that movements in rates would be translated more into price than volume movements in countries where these supply constraints are important. Notwithstanding recent developments in housing prices in Australia and elsewhere, we should therefore expect both structure and land prices to be *less* cyclical (and quantities more cyclical) on average in countries like Australia and the US than in continental Europe or Japan. It should also be expected that cycles in quantities would be more a feature of the Australian data, while the UK, with otherwise similar institutions in the mortgage market, would be more subject to cycles in housing prices.

Institutional details in the housing finance market also have a role in explaining the differing behaviour of construction and housing prices across countries and through time, and considerably complicate the story. The details of taxation arrangements and government intervention in the housing market might also make a difference, by determining where on the yield curve the mortgage market tends to operate.

We have estimated reasonably consistent, structurally motivated models for housing construction activity for a range of developed countries. However, these models do differ, and would be likely to have differed more if we had been trying to tune the individual country models closer to the data in each country. Quantitative findings about construction behaviour and policy transmission in one country are therefore likely to be inapplicable for other countries with different institutions. Although we have drawn out several likely factors explaining the differences in cyclicality and interest sensitivity in housing construction across countries, it is possible that these are not the only ones. Further research on these differences would therefore seem desirable in order to know whether lessons from one country are applicable to another.

Appendix A: Data Sources

Table A1: Data Definitions

Series	Definition
Dwelling investment	Gross fixed capital formation in dwellings at constant prices
Structure prices	Implicit price deflator for GFCF in dwellings
House prices	Median/mean price of dwellings at current prices
Housing starts	Number of new residential building starts
Housing stock	Total stock of dwellings
Number of households	Total number of households
Permanent income	Sum of non-durables and services consumption at constant prices
General price level	Level of the consumer price index
Construction costs	Weighted average of house building materials prices and labour costs at current prices
Policy interest rate	Interest rate targeted by central bank

Notes: The consumer price index for Australia excludes the effect of the GST. The weights for the construction cost variables are taken from countries' input-output tables. In the UK, we use household consumption expenditure as a proxy for permanent income. Some housing and demographic data are only available for Great Britain (i.e. excluding Northern Ireland) rather than for the entire UK. We have therefore had to rescale and interpolate these data to obtain a consistent data set for the UK. Details of these adjustments are available from the authors.

Table A2: Statistical Sources

Abbreviation	Full title
ABS	Australian Bureau of Statistics
BEA	Bureau of Economic Analysis
BLS	Bureau of Labor Statistics
BIS	Bank for International Settlements
CB	US Census Bureau
CMHC	Canada Mortgage and Housing Corporation
DTI	UK Department of Trade and Industry
NAR	National Association of Realtors
NIDSD	Northern Ireland Department of Social Development
ODPM	Office of the Deputy Prime Minister

Table A3: Data Sources

Series	Australia	Canada	UK	US
Dwelling investment	ABS Cat No *5206.0*	Stat Can *038-0010*	NS *DFEG*	BEA
Structure prices	ABS Cat No *5206.0*	Stat Can *038-0010*	NS *DFEG, DFDK*	BEA
House prices	CBA/HIA; Commonwealth Treasury; REIA	BIS	Nationwide	NAR *med. existing 1-family homes*
Housing starts	ABS Cat No *5750.0*, *5752.0*	CMHC	ODPM *211*; NS *FCAB, CTOR, CTOV*	CB *C20*
Housing stock	ABS Cat No *5752.0*, *Census*	Stat Can *v227368*; CMHC	ODPM *101*, *241*; NS *FCAB, CTOR, CTOV*	CB *Housing Vacancy Survey 7*
Number of households	ABS Cat No *3101.0*, *Census*	Stat Can *v227374*	ODPM *401*; NIDSD	CB *Housing Vacancy Survey 7*
Permanent income	ABS Cat No *5206.0*	Stat Can *380-0009*	NS *ABJR*	BEA
General price level	ABS Cat No *6401.0*; RBA	Stat Can *v735319*	NS *CHAW*	BLS *CUSR0000SA0*
Construction costs	ABS Cat No *6427.0*, *6302.0*, *5209.0*	Stat Can *v734362*, *v4331335*, *v4331326*, *329-0038*	NS *Labour Market Trends E.2, LNMQ; DTI*	BLS *wpusop2200*, *EEU20152006*
Policy interest rate	RBA	Bank of Canada	Bank of England	Federal Reserve

Notes: See Table A2 for abbreviations. Relevant catalogue, series and table identifiers are italicised. All series are seasonally adjusted, using conventional methods in Eviews where necessary. For consistency, annualised data are converted to quarterly values where appropriate.

Appendix B: Econometric Results

In the panel showing results for the dynamics, the numerical entries denote the sum of the coefficients on current values and lags of that variable. Where more than one lag of a variable is included, the sign of the first coefficient (current-dated or shortest lag) is shown as a subscript on the summation. The orders of the lags used are shown in parentheses alongside the reported coefficient sum. The significance levels of the first coefficient in the dynamics and of the long-run coefficients at the 10, 5 or 1 per cent levels are indicated by superscripted $*$, $**$ or †.

To conserve space and make interpretation easier, we report individual coefficients only for the long-run relationships in each equation. We report the sum of the coefficients on dynamic terms for each variable, with the range of contemporaneous or lagged variables indicated in parentheses alongside this summation. Sequences of lagged explanators can sometimes include coefficients with different signs, or where intermediate lags are not significant. We therefore also report the sign and significance of the estimated coefficient on the lowest lag of each variable as subscripts and superscripts to the sum of the coefficients.

Table B1: System Results – Australia

Equation	Supply mark-up		Total supply		Quantity demand		House prices	
Dependent variable	Δsp		Δhc		Δs		Δhp	
Long-run variables ($t-1$-dated)								
Starts (s)	$0.02^{\dagger}$		–		$-0.14^{\dagger}$		–	
Construction (hc)	–		$-0.17^{\dagger}$		–		–	
Costs (cc)	$0.07^{\dagger}$		–		–		–	
Housing prices (hp)	0.02^{**}		0.14^{**}		–		$-0.12^{\dagger}$	
Structure prices (sp)	$-0.11^{\dagger}$		-0.09		–		–	
Interest rates (i)	–		-0.00		–		–	
Income (y)	–		–		–		$0.16^{\dagger}$	
CPI (p)	–		-0.05		–		$0.12^{\dagger}$	
Vacancy rate (v)	–		–		$-3.42^{\dagger}$		-1.56^{**}	
Household growth (hh)	–		–		0.04		–	
Dynamics								
Δs	–		–		$0.51^{\dagger}_{+}$	(4–6)	–	
Δhc	–		0.17^{**}	(1)	–		–	
Δcc	$-0.33^{\dagger}_{-}$	(4–5)	–		–		–	
Δhp	$0.19^{\dagger}_{+}$	(2–3)	0.19^{**}_{+}	(1–6)	-0.46^{**}	(6)	$-0.24^{\dagger}$	(1)
Δsp	$0.52^{\dagger}_{+}$	(2–3)	0.15^{*}_{+}	(2–6)	-0.31^{**}_{+}	(1–4)	$1.61^{\dagger}$	(0)
Interest rates	$0.09^{\dagger}_{-}$	(2–3)	-0.21^{**}_{-}	(2–5)	$-0.68^{\dagger}$	(1)	$-0.42^{\dagger}$	(1)
Δy	–		–		$-10.48^{\dagger}_{-}$	(1–5)	$-0.74^{\dagger}$	(5)
Δp	–		-0.60^{*}	(6)	$-2.43^{\dagger}$	(2)	0.55^{**}	(3)
Δv	–		–		-23.28^{**}_{-}	(1–4)	$-8.25^{\dagger}$	(3)
Δhh	–		–		-0.12^{**}	(3)	–	
GST dummy	$0.08^{\dagger}$	(0)	-0.13^{*}_{+}	(4– -1)	$-0.11^{\dagger}_{+}$	(4–0)	$-0.30^{\dagger}$	(0)
Post-GST dummy	0.01^{**}		–		–		–	
Constant	$-0.31^{\dagger}$		0.52^{*}		$1.20^{\dagger}$		$-0.89^{\dagger}$	
R-bar squared	0.83		0.70		0.71		0.54	
Breusch-Godfrey LM	4.24		-0.59		-0.12		3.95	
Jarque-Bera	87.61		96.15		0.54		0.36	

Notes: Estimated 1975:Q4–2003:Q3. The GST dummy takes the value 1 for the 2000:Q3. The time indicators for the GST dummy refer to leads. The post-GST dummy takes the value 1 for every observation from 2000:Q3. Instruments for endogenous variables included lags of endogenous variables, construction costs and permanent income.

Table B2: System Results – United Kingdom

Equation	Supply mark-up	Total supply	Quantity demand	House prices
Dependent variable	Δsp	Δhc	Δs	Δhp
		Long-run variables ($t-1$-dated)		
Starts (s)	0.02	–	$-0.45^{\dagger}$	–
Construction (hc)	–	$-0.54^{\dagger}$	–	–
Costs (cc)	$0.24^{\dagger}$	–	–	–
Housing prices (hp)	$0.14^{\dagger}$	-0.10	–	-0.02^{*}
Structure prices (sp)	$-0.37^{\dagger}$	$0.73^{\dagger}$	–	–
Interest rates (i)	–	$0.11^{\dagger}$	–	–
CPI (p)	–	$-0.74^{\dagger}$	–	0.02^{*}
Vacancy rate (v)	–	–	$-4.90^{\dagger}$	0.13
Household growth (hh)I	–	–	$-0.15^{\dagger}$	–
Household growth (hh)II	–	–	0.07	–
		Dynamics		
Δs I	0.09^{**} (4)	–	–	$0.17^{\dagger}_{+}$ (0–4)
Δs II	–	–	–	$0.17^{\dagger}_{+}$ (0–4)
Δhc	–	$0.92^{\dagger}_{+}$ (3–6)	–	–
Δcc I	0.43^{**} (5)	–	–	–
Δhp I	-0.03^{**}_{-} (1–6)	1.58^{**}_{+} (2–6)	$-1.94^{\dagger}$ (4)	$0.60^{\dagger}_{+}$ (1–3)
Δhp II	-0.29^{**} (2)	1.58^{**}_{+} (2–6)	–	$0.60^{\dagger}$ (1–3)
Δsp I	0.37^{**}_{+} (2–4)	$-3.59^{\dagger}_{-}$ (1–4)	0.49^{**} (4)	–
Δsp II	$0.41^{\dagger}$ (4)	$-2.64^{\dagger}_{-}$ (1–3)	–	–
Interest rates I	–	$-0.81^{\dagger}$ (2)	$-2.35^{\dagger}$ (2)	$-0.23^{\dagger}$ (2)
Interest rates II	–	$-0.40\ast\ast$ (2)	0.62^{*} (5)	$-0.23^{\dagger}$ (2)
Δy I	–	–	$1.244^{\dagger}_{+}$ (2–3)	0.93^{**}_{+} (0–4)
Δy II	–	–	10.00^{**}_{+} (0–3)	0.93^{**}_{+} (0–4)
Δp I	–	$0.99^{\dagger}_{+}$ (1–6)	1.79^{**} (3)	$0.39^{\dagger}_{+}$ (0–1)
Δp II	–	$1.29^{\dagger}$ (1)	–	$0.39^{\dagger}_{+}$ (0–1)
1979 dummy	–	–	$-0.31^{\dagger}$	–
Constant I	$-1.18^{\dagger}$	$13.73^{\dagger}$	$7.03^{\dagger}$	0.10^{**}
Constant II	$-1.18^{\dagger}$	$13.73^{\dagger}$	$4.11^{\dagger}$	0.10^{**}
R-bar squared	0.59	0.43	0.36	0.64
Breusch-Godfrey LM	4.81	1.12	4.98	-3.87
Jarque-Bera	22.02	625.84	10.42	9.33

Notes: Estimated 1971:Q4–2003:Q2. Instruments for endogenous variables included lags of endogenous variables, construction costs and permanent income. A structural break is allowed for in 1986:Q1. Coefficients that apply only to the first segment of the data are labelled I, while those applying only in the second segment are labelled II. Dummy for 1979:Q1 to capture significant fall in starts.

Table B3: System Results – United States

Equation	Supply mark-up		Total supply		Quantity demand		House prices	
Dependent variable	Δsp		Δhc		Δs		Δhp	
Long-run variables ($t-1$-dated)								
Starts (s)	0.00		–		$-0.10^{\dagger}$		–	
Construction (hc)	–		$-0.19^{\dagger}$		–		–	
Costs (cc)	0.04		–		–		–	
Housing prices (hp)	0.04^{*}		0.22		–		$-0.07^{\dagger}$	
Structure prices (sp)	-0.06^{**}		0.05		–		–	
Interest rates (i)	–		$-0.02^{\dagger}$		–		–	
Income (y)	–		–		–		$0.09^{\dagger}$	
CPI (p)	–		-0.25^{**}		–		$0.07^{\dagger}$	
Vacancy rate (v)	–		–		-1.53		-0.11	
Household growth(hh)	–		–		0.01		–	
Dynamics								
Δs	–		–		-0.12	(3)	–	
Δcc II	-0.30^{*}	(0)	–		–		–	
Δhc I	–		$0.13^{\dagger}_{+}$	(1–4)	–		–	
Δhc II	–		$0.37^{\dagger}_{+}$	(1–2)	–		–	
Δhp I	$0.58^{\dagger}_{+}$	(2–3)	$6.42^{\dagger}_{+}$	(2–6)	$-3.08^{\dagger}$	(0)	$0.33^{\dagger}$	(5)
Δhp II	–		–		-1.79^{*}	(4)	–	
Δsp I	–		-4.15_{-}	(3–6)	–		$0.867^{\dagger}_{+}$	(0–3)
Δsp II	–		-1.56^{*}	(0)	–		$1.27^{\dagger}_{+}$	(2–5)
Interest rates (i) I	–		$-0.08^{\dagger}_{-}$	(2–3)	$-1.18^{\dagger}$	(0)	$-0.08^{\dagger}$	(3)
Interest rates (i) II	–		–		$-1.46^{\dagger}$	(2)	$0.14^{\dagger}_{-}$	(5–6)
Δy II	–		–		–		$-0.69^{\dagger}_{+}$	(0–2)
Δp I	–		$-6.16^{\dagger}_{-}$	(0–4)	$-1.17^{\dagger}_{-}$	(1–4)	–	
Δp II	–		$-6.16^{\dagger}_{-}$	(0–4)	–		$-0.27^{\dagger}_{-}$	(3–4)
Δv II	–		–		–		0.79^{**}	(2)
Constant I	-0.29^{**}		$3.25^{\dagger}$		$1.36^{\dagger}$		$-0.34^{\dagger}$	
Constant II	-0.29^{**}		$3.25^{\dagger}$		$1.36^{\dagger}$		$-0.36^{\dagger}$	
R-bar squared	0.47		0.51		0.14		0.53	
Breusch-Godfrey LM	0.84		4.99		4.66		2.01	
Jarque-Bera	408.20		37.21		2.22		0.48	

Notes: Estimated 1967:Q3–2003:Q2. Instruments for endogenous variables included lags of endogenous variables, construction costs and permanent income. A structural break is allowed for in 1986:Q1. Coefficients that apply only to the first segment of the data are labelled I, while those applying only in the second segment are labelled II.

Table B4: System Results – Canada

Equation	Supply mark-up	Total supply	Quantity demand	House prices
Dependent variable	Δsp	Δhc	Δs	Δhp
Long-run variables ($t-1$-dated)				
Starts (s)	$-0.02^{\dagger}$	–	$-0.42^{\dagger}$	–
Construction (hc)	–	-0.07^{**}	–	–
Costs (cc)	$0.09^{\dagger}$	-0.09	–	–
Housing prices (hp)	$0.14^{\dagger}$	-0.18^{**}	–	$-0.06^{\dagger}$
Structure prices (sp)	$-0.27^{\dagger}$	0.22	–	–
Interest rates (i)	–	0.00^{**}	–	–
Income (y)	–	–	–	–
CPI (p)	–	0.03	–	$0.06^{\dagger}$
Vacancy rate (v)	–	–	$-5.10^{\dagger}$	-0.32
Household growth (hh)	–	–	$0.25^{\dagger}$	–
Dynamics				
Δs	$0.02^{\dagger}$ (1)	–	-0.16^{**} (4)	–
Δhc	–	$-0.18^{\dagger}_{+}$ (1–4)	–	–
Δcc	-0.47^{*}_{+} (2–4)	$-1.56^{\dagger}$ (1)	–	–
Δhp	$0.37^{\dagger}_{+}$ (0–3)	$2.29^{\dagger}_{+}$ (0–5)	$2.17^{\dagger}_{+}$ (1–2)	$0.31^{\dagger}$ (4)
Δsp	0.37^{**}_{+} (1–4)	$-2.21^{\dagger}_{-}$ (1–4)	-1.42^{*} (4)	–
Interest rates	-0.00^{**}_{+} (1–2)	$-0.01^{\dagger}$ (0)	$-0.01^{\dagger}$ (0)	-0.00 (3)
Δy	–	–	$4.00^{\dagger}$ (3)	2.22^{**}_{+} (0–3)
Δp	–	$1.49^{\dagger}$ (2)	$5.57^{\dagger}$ (2)	–
Δv	–	–	$35.59^{\dagger}$ (1)	$-10.09^{\dagger}$ (3)
GST dummy	$0.04^{\dagger}$	-0.06^{**}	–	$0.10^{\dagger}$
GST dummy (-1)	–	–	–	$0.09^{\dagger}$
Post-GST dummy	-0.01^{**}	–	–	–
Constant	$0.41^{\dagger}$	1.50^{**}	$2.13^{\dagger}$	0.05^{*}
R-bar squared	0.74	0.63	0.52	0.36
Breusch-Godfrey LM	1.63	-0.37	-0.17	1.68
Jarque-Bera	0.50	0.72	3.49	0.78

Notes: Estimated 1976:Q4–2003:Q3. GST dummy takes the value 1 for the 1990:Q1. The post-GST dummy takes the value 1 for every observation from 1990:Q1. Instruments for endogenous variables included lags of endogenous variables, construction costs and permanent income.

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