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Migration and Business Cycle Dynamics

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Abstract

Shocks to net migration matter for the business cycles of some countries. Using an estimated dynamic stochastic general equilibrium (DSGE) model of a small open economy and a structural vector autoregression, we find that migration shocks account for a considerable proportion of the variability of per capita GDP. Migration shocks matter for the capital investment and consumption components of per capita GDP, but they are not the most important driver. Migration shocks are also important for residential investment and real house prices, but other shocks play a larger role in driving housing market volatility. In the DSGE model, the level of human capital possessed by migrants relative to that of locals materially affects the business cycle impact of migration. The impact of migration shocks is larger when migrants have substantially different levels of human capital relative to locals. When the average migrant has higher levels of human capital than locals, as seems to be common in most OECD economies, a migration shock has an expansionary effect on per capita GDP and its components.

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Migration, macroeconomics, business cycle fluctuations, Bayesian estimation, structural vector autoregression

JEL Classification

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Shocks to net migration matter for the business cycles of some countries. Using an estimated dynamic stochastic general equilibrium (DSGE) model of a small open economy and a structural vector autoregression, we find that migration shocks account for a considerable proportion of the variability of per capita GDP. Migration shocks matter for the capital investment and consumption components of per capita GDP, but they are not the most important driver. Migration shocks are also important for residential investment and real house prices, but other shocks play a larger role in driving housing market volatility. In the DSGE model, the level of human capital possessed by migrants relative to that of locals materially affects the business cycle impact of migration. The impact of migration shocks is larger when migrants have substantially different levels of human capital relative to locals. When the average migrant has higher levels of human capital than locals, as seems to be common in most OECD economies, a migration shock has an expansionary effect on per capita GDP and its components.

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1 Introduction

In recent years, migration flows have been large. Very large. Large in absolute numbers of migrants and large relative to non-migrant populations in destination countries. Migration flows caused by wars, economic uncertainty, and political instability have had substantial effects on migrants' origin and destination countries. The economic causes and consequences of migration are very complex; Kerr and Kerr (2011) and Nathan (2014) provide surveys that discuss various facets of migration, while Constant and Zimmermann (2013) and Chiswick and Miller (2015) provide handbooks on the topic. A particular focus of the literature has been on the effect of migration on the labour market (Borjas, 1999; Dustmann et al., 2005; Borjas, 2014; Burstein et al., 2017). Much of this analysis has a strong microeconometric focus,[1] sometimes based on partial equilibrium models or models that exploit cross-country or regional variation. The macroeconomic consequences of migration, and in particular the general equilibrium *business cycle* consequences, are less well understood and have not been researched in much depth in the international literature. One notable exception is the work by Mandelman and Zlate (2012), which focuses on international risk sharing via migrants' remittances.

In this paper, we focus on the role of migration shocks as a driver of the business cycle in countries-of-destination. How does migration affect the per capita level of gross domestic product (GDP) and its components? How does migration affect the real exchange rate, and finally, do shocks to migration drive the business cycle?

To address these questions, we develop and estimate a dynamic stochastic general equilibrium model for a small open economy that experiences net migration flows. We fit this model to the New Zealand economy, because of the availability of excellent migration data. All arrivals and departures in New Zealand are subject to reporting requirements and virtually all migrants arrive or depart by air, which provides a natural bottleneck for data collection. Migration flows into New Zealand have also been substantial in recent years, providing much-needed variation for econometric analysis. For example, net migration has increased working-age population in New Zealand by 1 percent in each of the three years from 2015-2017, and continues at a fast pace in 2018. While geographically remote, New Zealand is a developed economy with judicial and institutional frameworks that are

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[1] See, for example, the discussion paper series of the Centre for Research and Analysis of Migration.

similar to other developed countries. The structural parameters that we estimate for the New Zealand economy are in line with those for other advance economies, and our analysis is thus likely to be informative for other countries experiencing similar migrant flows.

Our analysis enables us to determine the contribution of migration shocks to the business cycle. We illustrate that the skill level of migrants relative to locals materially influences the dynamic impact of migration on the host economy. Borjas (1999) notes that "the labour market impact of immigration hinges crucially on how the skills of migrants compare to those of natives in the host country". We show that relative skill levels also matter for macroeconomic aggregates such as consumption and investment, in addition to labour market variables such as hours worked and wages. Migration shocks account for more of the volatility of the business cycle if migrants' level of human capital differs from that of locals. If migrants have a higher level of human capital than locals, the effects of migration are expansionary on a per capita basis and migration shocks can account for a large fraction of the volatility of GDP and its components. When migrants have the same human capital as locals, migration shocks account for only a small fraction of the overall volatility of GDP. While still expansionary on a per capita basis, this kind of migration causes much less volatility for the host economy.

The literature on the business cycle effects of migration can be traced back to Jerome (1926), who explored the implications of immigration into the United States in the early twentieth century. However, the modern literature on the macroeconomic effects of migration, using time series and structural macroeconomic models, is relatively sparse. Our work is related to Weiske (2017a,b), who look at the macroeconomic effects of migration and population growth in the United States (US). Using constructed working-age net migration data for the United States in a vector autoregression, Weiske (2017a) finds that the short-run effects of migration are consistent with standard growth theory, ie real wages fall and investment increases. However, Weiske also finds that migration shocks make only a modest contribution to US business cycle dynamics. The latter result is not entirely surprising, since data from the Department of Homeland Security and the US Census Bureau suggest that the per annum migration rate for the United States has been below 1 percent since 1915 and, with two exceptions, has been below 0.4 percent since 1925.[2]

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[2] See `https://www.dhs.gov/immigration-statistics/yearbook/2016/table1` and the Haver population series A111POPG10. These percentages are indicative since the immigration series are for fiscal years, and do not align perfectly with the Census numbers.

For some countries, the effects of migration shocks are more substantial. Furlanetto and Robstad (2016), for example, use Norwegian data and find that positive migration shocks are expansionary and are a major driver of the dynamics of unemployment, though they are unimportant for house prices. Barrell et al. (2010) examine a particular facet of migration, namely the migration that occurred following the accession of ten Eastern European countries into the European Union, highlighting large flows into Ireland and the United Kingdom. In a Bundesbank working paper, Stähler (2017) examines the macro impact of refugees in Germany. In Stähler's model, refugees from the rest-of-the-world are absorbed only gradually into the labour force. Refugees initially increase output, via a demand channel, but the later dynamics depend on whether refugees accumulate more or less qualifications than locals.

In New Zealand, much of the literature on migration focuses on the housing market. Using a structural vector autoregression, Coleman and Landon-Lane (2007) find that migration has an extremely large impact on house prices, unlike the result reported for Norway by Furlanetto and Robstad (2016). Stillman and Maré (2008) apply microeconometric techniques to New Zealand census and house sales data to examine the impact of population and migration on house prices at a local, disaggretated level; they find no impact of foreign-born migrants on local house prices, though returning New Zealanders seem to have a statistically significant impact. In contrast, McDonald (2013) investigates the composition of New Zealand migration and finds that constituent parts of net migration have different macro consequences: migrant arrivals are found to have more substantial impact on house prices than migrant departures and the citizenship of migrants also appears to have implications for the domestic (New Zealand) impact of migration. In a similar vein, Vehbi (2016) finds that the age-composition of migrants matters, with (presumably wealthier) 30-49 year old migrants having more substantial effects on consumption, house prices, rents, and residential investment than 17-29 year old migrants.

Having briefly described the literature we now turn to the specification of the structural model that we use to investigate the impact of migration flows on the business cycle.

2 A model of migration in a small open economy

We analyse the effects of migration shocks on business cycle dynamics using a dynamic stochastic general equilibrium (DSGE) model of a small open economy. The standard small open economy model is augmented with two features that have non-trivial implications for the economy's dynamic response to migration shocks. First, we allow for human capital accumulation, such that migration can affect not just the physical capital stock per head, but also the stock of human capital per capita. Importantly, the two forms of capital need not be affected by a migration shock in the same way. Second, we introduce a residential housing sector into the model. This addition allows us to analyse the effect of migration on residential real estate prices, and also sectoral labour flows. In other words, does migration cause labour to flow from the production of goods into the production of houses? We briefly discuss these two modelling choices in relation to the macroeconomic environment in New Zealand.

New Zealand's Immigration Act 2009 provides the current framework for migration into New Zealand. This legislation is augmented with regulations that specify application requirements for different visa categories. Visas are available for entrepreneurs, investors, skilled migrants, refugees, Pacific Islanders, and others. Of most note, in the context of our analysis, is the use of points-based criteria to rank applicants for many visa categories. Comparatively little use is made of visa ballots,[3] such as those used to allocate 'Diversity Immigrant Visas' (green cards) in the United States. In the ten and a half years from fiscal year 2007/8, roughly 463 thousand migrants have had visa applications approved by New Zealand immigration authorities.[4] Some 263 thousand successful applicants (circa 57 percent of successful applicants) entered New Zealand as 'Skilled Migrants' or via investor, entrepreneur or other skill-related categories. A further 163 thousand migrants (35 percent) were approved for family-related reasons, around 15 thousand visas (3.2 percent) were granted for refugees, 16 thousand visas were approved for people from the Pacific (3.5 percent); and a little over 5 thousand people were provided visas for various other reasons (primarily by ministerial direction). While the measurement of human capital is clearly fraught, the importance of skilled, investor, and entrepreneurial migrants provides some support for the

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[3] There are exceptions to this generalisation: Gibson et al. (2018) discuss the effects of migration on Tongan migrants who enter into New Zealand via a lottery.

[4] See `https://www.immigration.govt.nz/documents/statistics/r1residencedecisionsbyfy.zip`, downloaded 8 February 2018.

view that the ‘average’ migrant might have more human capital than domestic residents.

As mentioned above, we also explicitly model the housing sector. We incorporate housing into our analysis because housing is an important component of the capital stock, and demand for houses is directly and immediately affected by an increase in population – from migrants and residents alike. Residential investment is also one of the most volatile components of gross domestic product, contributing to business cycle fluctuations. Furthermore, construction is an important sector of the New Zealand labour market. According to the Quarterly Employment Survey, the proportion of full-time equivalents employed in construction has increased from below 5 percent in the early 1990s to around 9 percent in the most recent data in 2017. The links between house values and consumption (and therefore aggregate demand) also receives continued emphasis in the monetary policy statements of the Reserve Bank of New Zealand, in part reflecting the fact that a substantial proportion of New Zealanders' domestic wealth is tied up in home ownership.

2.1 Households

In our model, households maximise expected utility defined over consumption, housing services, labour effort, and skill accumulation. The period utility function is

$$U_t = \left(j_t^c \ln c_t + j_t \ln h_t - \frac{\phi_0}{1+\eta} (n_t + s_t)^{1+\eta} \right) \tag{1}$$

where c_t is consumption per capita, h_t are housing services per capita, j_t^c and j_t are shocks that affects the utility agents derive from consumption and housing services, respectively. n_t denotes working hours, and s_t is on-the-job training hours per capita. The final consumption good, c_t, consists of a domestically produced good, c_t^h, and an imported good, c_t^f. More precisely, the final good is defined as a constant elasticity of substitution (CES) aggregate:

$$c_t = \left[v^{\frac{1}{\theta}} \left(c_t^h \right)^{\frac{\theta-1}{\theta}} + (1-v)^{\frac{1}{\theta}} \left(c_t^f \right)^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}} . \tag{2}$$

Here θ denotes the elasticity of substitution between the two types of goods and v is the share of the domestically produced good in final consumption. The price index of the final good, P_t, is chosen to be the numeraire. Consequently, all other prices are expressed relative to the home final good. For example, the relative price of domestically produced goods, p_t^h, denotes the ratio $\frac{P_t^h}{P_t}$.

Households maximise expected utility subject to the flow budget constraint:

$$\begin{aligned} c_t + p_t^f b_t + q_t^H h_t + p_t^l l_t =& (1+r_{t-1}) p_t^f \frac{N_{t-1}}{N_t} b_{t-1} + q_t^H (1-\delta_h) \frac{N_{t-1}}{N_t} h_{t-1} \\ &+ w_t n_t \frac{N_{t-1}}{N_t} d_{t-1} + (p_t^l + R_t^l) \frac{N_{t-1}}{N_t} l_{t-1} + \pi_t \end{aligned} \tag{3}$$

Households consume goods, c_t, buy bonds that pay out in units of foreign-produced goods, b_t, buy housing services, h_t at price q_t^H, and buy land, l_t at price p_t^l. Households finance these expenditures through wage income, $w_t n_t d_t$ (reflecting both hours n_t and human capital d_t); the return they receive from the bonds purchased in the previous period, $(1+r_{t-1})b_{t-1}$; from the rental returns to their land holdings, $R_t^l l_{t-1}$; from selling the un-depreciated housing services purchased last period, $(1-\delta_h)h_{t-1}$; and through dividend income, π_t that accrues to households as owners of the production sector. The stock of human capital, denoted d_t, evolves according the following law of motion:

$$d_t = (\frac{N_{t-1}}{N_t} d_{t-1} s_t)^{\phi_s} N_t^{2\phi_s - 1} + (1-\delta^d) \frac{N_{t-1}}{N_t} d_{t-1} \tag{4}$$

where $(d_{t-1}s_t)^{\phi_s}$ denotes the production technology that turns effective time investment into human capital and δ^d denotes the depreciation rate of human capital. In modelling the accumulation of human capital we largely follow Kim and Lee (2007). Setting the parameter $\phi_s < 1$ ensures that growth is exogenous. In our case with exogenous population growth we have to set $\phi_s = 1/2$ to rule out a scale effect from population growth.

The size of the working-age population at time t is denoted by N_t. Expressing all variables in the model on a per capita basis implies that all carried-over stocks, such as housing, bonds, human capital and land in equation (3) are deflated by the term $\frac{N_{t-1}}{N_t}$, which is the inverse of the gross growth rate of working-age population.

2.2 Household's first order conditions

Equations (5) - (11) are the optimality conditions for consumption, hours worked, hours spent training, the accumulation of human capital, bonds, housing, and land. The marginal utility of consumption at time t in these equations is denoted μ_t and the multiplier on the accumulation constraint for human capital is denoted λ_t.

$$j_t^c/c_t - \mu_t = 0 \tag{5}$$

$$-\phi_0(n_t + s_t)^\eta + \mu_t w_t \frac{N_{t-1}}{N_t} d_{t-1} = 0 \tag{6}$$

$$-\phi_0(n_t + s_t)^\eta + \lambda_t \phi_s \frac{(\frac{N_{t-1}}{N_t} d_{t-1} s_t)^{\phi_s}}{s_t} = 0 \tag{7}$$

$$-\lambda_t + \mu_t w_t n_t + \beta E_t \lambda_{t+1} \left[\phi_s \frac{(s_{t+1}\frac{N_t}{N_{t+1}} d_t)^{\phi}_{s}}{d_t} + (1-\delta^d)\frac{N_t}{N_{t+1}} \right] = 0 \tag{8}$$

$$-\mu_t + \beta E_t \mu_{t+1} \frac{p_{t+1}^f}{p_t^f} \frac{N_t}{N_{t+1}} (1 + r_t) = 0 \tag{9}$$

$$-q_t^H + j_t \frac{1}{(h_t \mu_t)} + \beta E_t \frac{N_t}{N_{t+1}} \frac{\mu_{t+1}}{\mu_t} \left((1-\delta_h) q_{t+1}^H \right) = 0 \tag{10}$$

$$-p_t^l + \beta E_t \frac{N_t}{N_{t+1}} \frac{\mu_{t+1}}{\mu_t} \left(p_{t+1}^l + R_{t+1}^l \right) = 0 \tag{11}$$

2.3 Firms

Households supply firms with *effective labour*, defined as $n_t d_{t-1} \frac{N_{t-1}}{N_t} = en_t$, which is remunerated with the real wage w_t. Note that the opportunity cost of investing in human capital is borne exclusively by the household and not the firm. Households divide total effective labour, en_t, between the goods producing sector, supplying en_t^y units of labour, and the construction sector, supplying en_t^H units of labour.

$$en_t = en_t^y + en_t^H \tag{12}$$

2.3.1 Goods sector

Goods-producing firms produce a tradable good y_t whose price in terms of the numeraire good is p_t^h. Firms maximise cash-flow defined as the difference between the value of output and expenditure on wages and investment, x_t:

$$\pi_t^y = p_t^h y_t - w_t en_t^y - x_t \tag{13}$$

subject to a production technology that combines effective labour and utilised capital:

$$y_t = a_t(u_t \frac{N_{t-1}}{N_t} k_{t-1})^{\alpha}(en_t^y)^{1-\alpha}. \tag{14}$$

The usual law of motion of the capital stock is defined as:

$$k_t = (1-\delta(u_t))k_{t-1}\frac{N_{t-1}}{N_t} + a_t^i \iota(x_t/x_{t-1}). \tag{15}$$

where the depreciation rate $\delta()$ is a function of the utilisation rate, u_t. The function $\iota(x_t/x_{t-1})$ represents investment adjustment costs, as per Christiano et al. (2005), and a^i denotes a shock to the marginal efficiency of investment (MEI). The standard optimality condition for capital and investment are:

$$q_t = E_t \beta \frac{N_t}{N_{t+1}} \frac{\mu_{t+1}}{\mu_t} \left(p_{t+1}^h \frac{\partial y_{t+1}}{\partial k_t} + q_{t+1}(1-\delta(u_{t+1})) \right) \tag{16}$$

$$1/a_t^i = q_t \frac{\partial \iota(x_t, x_{t-1})}{\partial x_t} + \beta E_t \left(\frac{\mu_{t+1}}{\mu_t} q_{t+1} \frac{\partial \iota(x_{t+1}, x_t)}{\partial x_t} \right) \tag{17}$$

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$$\alpha p_t^h \frac{y_t}{u_t} = q_t \delta'(u_t) k_t \tag{18}$$

2.3.2 Construction sector

Our housing and construction sector is based on Iacoviello (2005). Housing stock is built using effective labour, land and home-produced intermediate goods, m_t. Profits in the construction sector at time t are defined as π_t^H, with

$$\pi_t^H = q_t^H H_t - w_t en_t^H - R_t^l l_{t-1} - p_t^h m_t \tag{19}$$

where q_t^H denotes the price of newly built housing stock. Labour mobility across sectors ensures that builders face the same wage costs as do goods producing firms, w_t. The rental rate of land faced by the construction sector is denoted by R_t^l. Profits are maximised subject to the following production technology for new housing:

$$H_t = a_t^H \left(\frac{N_{t-1}}{N_t} l_{t-1} \right)^{\xi_l} {en_t^H}^{1-\xi_l-\xi_m} m_t^{\xi_m} \tag{20}$$

The production of houses is, like the production of goods, subject to an AR(1) technology shock, a_t^H. The construction firm maximises profits by choosing effective labour, land and intermediate inputs optimally:

$$(1 - \xi - \xi_m) q_t^H \frac{H_t}{en_t^H} = w_t \tag{21}$$

$$\xi_l q_t^H \frac{H_t}{l_{t-1}} = R_t^l \tag{22}$$

$$\xi_m q_t^H \frac{H_t}{m_t} = p_t^h \tag{23}$$

Every period, households sell their un-depreciated housing stock and purchase new homes with the proceeds. Market clearing implies that the supply of new houses equals the net increase in the housing stock.

$$H_t = h_t - (1 - \delta_h) \frac{N_{t-1}}{N_t} h_{t-1} \tag{24}$$

The total amount of land in the economy is fixed, but as the population grows the supply of land per household diminishes. A temporary increase in migration, or indeed just natural population growth, would imply an ever decreasing amount of land per household. From a modelling perspective, the steady state around which we are linearising the model would therefore not be deterministic. We get around this problem by assuming that land is re-zoned for building purposes as the population grows. As the supply of building land grows along with the population, the supply of land per household remains constant:

$$l_t = 1. \tag{25}$$

2.4 Current account

Having described the household and production sectors above, this section presents the final equations needed to close the model. Market clearing in the goods market is described by equation

(26):

$$y_t - m_t = v \left(p_t^h\right)^{-\theta} (c_t + x_t) + ex_t^h. \tag{26}$$

The home produced good is used in the production of the domestically consumed final good and the domestically used investment good, and is also exported and used in construction. Export demand from abroad is assumed to be of the form:

$$ex_t^h = v^* \left(\frac{rer_t}{p_t^h}\right)^{\theta^*} y_t^* \tag{27}$$

with y_t^* denoting total foreign demand for the domestic good. Substituting the market clearing conditions from the goods and labour markets into the household budget constraints yields the economy-wide current account equation:

$$y_t = c_t + x_t + m_t + p_t^f b_t - p_t^f (1 + r_{t-1}) \frac{N_{t-1}}{N_t} b_{t-1} \tag{28}$$

Finally, we close the model by introducing a debt elastic interest rate premium that allows for small deviations of the domestic real interest rate from the world rate when the domestic net foreign asset position deviates from its steady state level. This eliminates the unit-root in bond holdings:

$$1 + r_t = (1 + r_t^*) e^{-\phi_b (b_t - \bar{b})} \tag{29}$$

2.5 Driving processes

The model economy is driven by seven shocks all of which take the shape of an AR(1) process:

$$a_t = \rho_a a_{t-1} + \epsilon_{at} \tag{30}$$

$$a_t^H = \rho_h a_{t-1}^H + \epsilon_{ht} \tag{31}$$

$$j_t = \rho_j j_{t-1} + \epsilon_{jt} \tag{32}$$

$$j_t^c = \rho_{jc} j_{t-1}^c + \epsilon_{jc t} \tag{33}$$

$$a_t^i = \rho_i a_{t-1}^i + \epsilon_{it} \tag{34}$$

$$y_t^f = \rho_y y_{t-1}^f + \epsilon_{yf t} \tag{35}$$

$$v_t = \rho_v v_{t-1} + \epsilon_{vt} \tag{36}$$

Equations (30) and (31) are total factor productivity processes in goods production and construction, respectively. Equations (32) and (33) represent preference shocks for housing and consumption, while (34) denotes the MEI shock process. World output and net migration follow the processes denoted in (35) and (36). Specifically, the migration process is defined as $v_t \equiv \ln(N_t/N_{t-1})$.

Modelling migration as an exogenous process is a simplifying assumption, with some empirical support in our reduced form analysis, depending on how the model is specified. The literature also provides a degree of support for this assumption. Mitchell et al. (2011) find that simple autoregressive models can provide more accurate forecasts of migration in the United Kingdom than models that include economic or policy factors – in part because policy factors are hard to forecast.[5]

3 Migration versus population growth

What is the key difference between migration and population growth? In the model, the main effect of both migration and population growth is to dilute existing stocks of capital, housing, human

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[5] Conversely, theory emphasizes that migration should be endogenous to domestic and foreign conditions, see for example Borjas (1999). Alternative empirical methodologies do uncover endogenous effects at some frequencies: Mayda (2010), for example, conducts a panel data analysis based on annual data from 14 developed countries and finds that 'pull' factors in destination economies, such as relative income levels, do affect migration flows, though 'push' factors have only small effects.

capital, and net foreign assets on a per capita basis. What differentiates migration from population growth is that for human capital, at the very least, migration need not reduce the per capita level of the relevant stock. Indeed, migration may even raise the average human capital in the economy.

To illustrate the effect of migrants arriving with human capital, consider the log-linearised evolution of d_t over time when migrants arrive with no human capital:

$$\hat{d}_t = \phi_s \delta^d \left[\hat{d}_{t-1} - v_t + \hat{s}_t\right] + (1-\delta^d)\left[\hat{d}_{t-1} - v_t\right] \tag{37}$$

Unskilled migration reduces the per capital stock of human capital in the economy. Skilled migration in the model would imply that the evolution of human capital per head is not affected by migration. We thus amend the equation above as:

$$\hat{d}_t = \phi_s \delta^d \left[\hat{d}_{t-1} - (1-\chi)v_t + \hat{s}_t\right] + (1-\delta^d)\left[\hat{d}_{t-1} - (1-\chi)v_t\right] \tag{38}$$

where χ is strictly positive and takes the value of 1 when migrants possess the same level of human capital as natives, or greater than 1 when migrants have a higher average level of human capital.

4 Estimation strategy

The principal aim of our model is to shed light on the short-run macroeconomic effects of migration shocks and assess their contribution to the dynamics of the business cycle. To this end, we implement a Bayesian estimation procedure. We estimate the model using macroeconomic data for New Zealand, an economy that has experienced both large and volatile migration flows in recent decades. In addition, New Zealand is one of the very few countries for which reliable data on working-age net migration is available.

We focus our analysis on 'permanent and long-term' (PLT) arrivals and departures. PLT arrivals are people arriving for a stay of 12 months or more, including New Zealanders returning after an absence overseas of 12 months or more. Conversely, PLT departures are New Zealanders departing for 12 months or more and migrants leaving after a stay of 12 months or more in New Zealand. Net migration figures in New Zealand are often decomposed into net migration between New Zealand and Australia and net migration relative to the rest of the world. Australian and New Zealand citizens largely have freedom of movement between the two countries, including the right to work. In Figure 1, net migration between New Zealand and Australia is summarised by the blue bars and that between New Zealand and the rest of the world by the red bars.[6] Over the sample, there was negative net migration between New Zealand and Australia, offset by positive migration between the rest of the world and New Zealand. Since about 2014, net migration to Australia has dried up, while net migration into New Zealand from the rest of the world has increased. As a result, annual net migration has risen to about 1.5 percent of the total resident population, while working-age migration has increased by a slightly larger percentage. In the four years 2014-2017, working age population increased by over 5.5 percent from net migration alone.

4.1 Data

We use national accounts data, migration data, house price data, and a trade-weighted aggregate of world gross domestic product (GDP) to estimate the model. The national account and migration data are sourced from Statistics New Zealand, while the house price data are from Quotable Value New Zealand. The trade-weighted world GDP data are compiled by the Reserve Bank of New Zealand. The data sample runs from 1992Q1-2017Q2.

GDP, residential investment, gross fixed capital formation (investment), and private consumption are sourced from the national accounts. We also use a trade-weighted measure of world GDP and working age net migration. All series are seasonally adjusted. The national accounts and migration data are transformed into per capita terms by dividing by seasonally-adjusted working age (15-65 year old) population. We take the natural logarithm of trending series and then apply the local linear projections of Hamilton (2017) to compute the trends, and hence cycles, of the data series.[7] This de-trending method is particularly straightforward to implement and consists of regressing the representative data series x_{t+h} against a constant and the data x_t, x_{t-1}, x_{t-2}, and x_{t-3}, where $h = 8$ quarters. This filter is one-sided and thus avoids the so-called 'end-point' problem commonly associated with the Hodrick-Prescott filter. The filter has the added advantage that, given that four lags are used, it simultaneously strips out seasonality. Cycles derived from seasonally adjusted data and unadjusted data are virtually indistinguishable. Furthermore, the

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[6] These numbers are based on the destination country and country of origin, rather than country of citizenship.

[7] The migration series is not logged as it takes both positive and negative values.

detrended series also has a mean of zero provided that a constant is included in the local linear projection. (See Hamilton 2017 for a thorough discussion of the virtues of this detrending method.) As the filter is not yet widely used, and as our migration data are not well-known, we illustrate the detrended data in figure 2. As can be see in the figure, the cycles obtained from a seasonally adjusted series and from an unadjusted migration series are virtually identical.

Over the course of our sample working age population has increased rapidly, from around 2.66 million people in 1992 to 3.84 million in 2017Q2, making it difficult to translate percentage changes into the number of migrants entering the country. The largest quarterly migrant impulse in the raw data in percentage terms corresponded to an increase in working age population of 0.4 percent in a single quarter, in 2015Q4. In this quarter (in unofficially seasonally adjusted terms) a little more than $15,100$ working age PLT migrants entered the country in raw terms.

The standard deviation of the *detrended* migration series is 0.00125 in quarter-on-quarter percent terms. Thus, in an ordinary year a one standard deviation increase in population from migration corresponds to roughly a 1/2 percent of working age population. The largest detrended seasonally adjusted migration inflow in a quarter, 0.0031 percent, occurred in 2003Q1, and was nearly $2\frac{1}{2}$ times as large as the standard deviation of the detrended series. Approximately $10,500$ working age migrants entered New Zealand in that particular quarter in the raw data.

The rest-of-world gross domestic product series is a trade-weighted average of the GDPs from 17 countries. We have backcast the series 2 quarters using an earlier vintage of this trade-weighted GDP, based on slightly fewer countries. Working age net migration is computed from Statistics New Zealand's permanent and long-term arrivals and departures data. The working-age data are assembled from age cohort data. We seasonally adjust the per capita working-age net migration data using a default implementation of X12.[8] Table 1 defines the raw data, while table 2 describes the transformations applied to the raw data.

Table 3 reports the standard deviations, the standard deviation of variable i relative to that of GDP and first-order autocorrelation to the observables. New Zealand GDP per capita is considerably more volatile than our measure of World GDP. Residential investment is 5.67 times as volatile as GDP and more volatile than gross fixed capital formation (investment). Real house prices are

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[8] The executable file for X12 is available from the United States Census Bureau. We use an X12 implementation embedded in IRIS, `https://github.com/IRIS-Solutions-Team`.

3.8 times as volatile as GDP. Unlike most other developed economies, New Zealand consumption is somewhat more volatile than GDP. Net migration per capita in New Zealand is volatile by OECD standards, but is still only about 5% as volatile as real GDP.

4.2 Calibration and priors

Columns 3 - 5 of Table 4 report the priors, means and the standard deviations of the parameters to be estimated. Most of our priors are fairly standard, see for instance Kamber et al. (2015). We do however, differ from the literature along several dimensions. Specifically, we attach a very tight prior to the share of capital, α, with a prior mean of 0.33, as is standard in the real business cycle literature. Likewise, the AR(1) coefficients for world GDP and net migration, ρ_{yf} and ρ_v respectively, have a prior that corresponds to estimates of these coefficients from single equation methods, as do the standard errors of the these two shocks, ϵ_{yf} and ϵ_v. In each case, we estimate the parameter, but choose a relatively small standard error for our prior. These tight priors are implemented to prevent biases in the domestic equations from contaminating our estimates of these foreign impulses via the systems estimation of the model.

Preliminary efforts to estimate the ratio of human capital for migrants relative to domestic residents, χ proved problematic, so we calibrate this parameter and later report a sensitivity analysis to illustrate how the dynamics of the model are affected by this parameter. The bottom half of Table 4 reports the calibrated parameters. Most of these are standard and only two parameters merit a special mention: the ratio of residential investment to consumption, which we set at 0.12 to match New Zealand data, and the above mentioned parameter χ, which we set at 1.85. The latter value is the relative level of human capital of migrants into New Zealand as reported in Boubtane et al. (2016). We carry out sensitivity analysis around our choice of is parameter value in section 6.

4.3 Estimation results

Columns 6 - 8 of Table 4 report the posterior mean and lower and upper limits of 90% Bayesian confidence intervals from the posterior distribution. The share of capital in the production of goods has a posterior mean of 0.33 and the share of land in the housing sector one of 0.61. Capital depreciates 2.7 percent per quarter. The inverse of the labour supply elasticity, η, has a posterior

Table 1: Raw data

Symbol	Description	RBNZ identifiers
GDP	Production GDP seasonally adjusted	ngdpp_z
I^{res}	Private residential investment seasonally adjusted	nipd_z
X	Gross fixed capita formation seasonally adjusted	ni_z
C	Private consumption seasonally adjusted	ncp_z
pop^{wa}	Working age (15-65 year old) population	lhpwa_z
M	Net perm./long-term migration 15-65 year old	–[†]
q^h	Quotable Value House price index	pqhpi
CPI	Consumer price index	pcpis[‡]
GDP^*	Trade-weighted rest-of-world GDP	IWGDP_Z

[†] Arrivals less departures. [‡] The CPI series used here slightly deviates from headline CPI in the early 1990s, as it excludes interest charges, which were incorporated in headline CPI at that time. The data are available from the authors upon request.

mean of 3.7. The trade elasticity or the intra-temporal elasticity of substitution between home and foreign produced goods is estimated at 2.55, which implies that home and foreign-produced goods are highly substitutable for one another. The openness parameter, γ, also has a tight prior and corresponds to the ratio of exports plus imports to GDP. For New Zealand, this value is around 0.33. Parameters acu and ac are the capacity utilisation elasticity and the investment adjustment cost parameter, respectively. ϕ^b measures the bond holding costs. The data suggests a low mean value 0.2 of one percent.

Total factor productivity (TFP) in goods production and housing is persistent, with estimated AR(1) coefficients of 0.76 and 0.72, respectively. The corresponding standard deviations of the innovations are 0.03 and 0.04, respectively. The shocks to preferences for housing and consumption have AR(1) coefficients of 0.86 and 0.83, respectively. Whereas these two shocks have a similar persistence, the housing preference shock is more volatile than the consumption shock. The investment specific technology shock has a low autocorrelation coefficient and large standard deviation. The magnitude of this shock process is similar to estimates from Kamber et al. (2015). Working age migration per capita, estimated with a tight prior, is persistent with an associated AR(1) coefficient of 0.89 and a standard deviation of the migration impulse of 0.001.

Table 2: Data transformations

Description	Symbol
Detrended log per capita income	$y = HAM(\log(GDP/pop^{WA}))$
Detrended log per capita residential investment	$H = HAM(\log(I^{res}/pop^{WA}))$
Detrended log per capita gross fixed capital formation	$x = HAM(\log(X/pop^{WA}))$
Detrended log per capita private consumption	$c = HAM(\log(C/pop^{WA}))$
Detrended log real house prices	$q^h = HAM(\log(P^h \cdot 1000/CPI))$
Detrended migration per capita	$v = HAM(M/pop^{WA})$
Detrended log trade-weighted foreign GDP	$y^* = HAM(\log(GDP^*))$

$HAM()$ represents the Hamilton filter, log() is the natural logarithm. A Matlab file implementing these transformations is available upon request.

Table 3: Observables and model moments

	Std Dev (σ)	σ_i/σ_y	Corr(Y_t, Y_{t-1})
GDP per capita	0.0264	1	0.8453
Residential Investment per capita	0.1496	5.67	0.8694
Investment per capita	0.1134	4.30	0.8297
Consumption per capita	0.0275	1.04	0.8408
Real House Prices	0.1006	3.81	0.8715
World GDP	0.0164	0.62	0.8864
Migration per capita	0.0013	0.05	0.8904

Note: All data, except for net migration per capita, are in logs and and all are de-trended using the Hamilton filter.

Table 4: Estimated parameters values

Parameter	Description	Prior	Mean	Std Dev	Post. Mean	(5%	95%)
α	Share of capital	N	0.330	0.010	0.330	0.314	0.346
α_h	Share of land in housing	N	0.700	0.050	0.614	0.561	0.667
δ	Depreciation rate capital	N	2.500	0.500	2.748	1.944	3.538
η	Frisch elasticity	Γ	2.000	0.750	3.733	2.211	5.251
θ	Intratemp. subst. elasticity	N	1.000	0.250	2.550	2.498	2.590
γ	Openness	β	0.300	0.010	0.337	0.321	0.353
acu	Capacity-U curvature	β	0.500	0.150	0.669	0.479	0.865
ac	Investment adjustment costs	N	4.000	1.500	6.313	4.433	8.131
$\phi^b \times 100$	Bond adjustment costs	Γ^{-1}	1.000	5.000	0.205	0.152	0.256
ρ_a	Persistence tech.	β	0.500	0.200	0.762	0.710	0.814
ρ_{ah}	Persistence housing tech.	β	0.500	0.200	0.718	0.613	0.826
ρ_y	Persistence foreign demand.	β	0.886	0.010	0.887	0.871	0.903
ρ_j	Persistence housing pref.	β	0.500	0.200	0.860	0.806	0.917
ρ_{jc}	Persistence consumption pref.	β	0.500	0.200	0.830	0.780	0.879
ρ_i	Persistence investment-specific	β	0.500	0.150	0.272	0.145	0.397
ρ_v	Persistence migration	β	0.890	0.010	0.890	0.874	0.906
ϵ_a	Std dev. tech.	Γ^{-1}	0.004	1.500	0.030	0.026	0.034
ϵ_h	Std dev. housing tech.	Γ^{-1}	0.005	1.500	0.038	0.032	0.043
ϵ_{yf}	Std dev. foreign demand	Γ^{-1}	0.007	1.500	0.007	0.006	0.008
ϵ_j	Std dev. housing pref.	Γ^{-1}	0.005	0.500	0.535	0.335	0.728
ϵ_i	Std dev. investment-specific	Γ^{-1}	0.005	1.500	0.366	0.244	0.483
ϵ_{jc}	Std dev. consumption pref.	Γ^{-1}	0.004	1.500	0.034	0.030	0.039
ϵ_v	Std dev. migration	Γ^{-1}	0.001	1.500	0.001	0.001	0.001

	Calibrated	
χ	Relative human cap of migrants	1.85
$\delta_h \times 100$	Depreciation rate housing	1
β	Discount rate	1/1.01
δ_d	Depreciation rate human cap.	0.01
ϕ_s	Skill accumulation	0.5
$\bar{j}$	Steady-state j	0.7
$n + s$	Hours worked + training	1/3
ξ_m	Share of traded goods in housing	0.1
H/c	H - C ratio	0.12

Table 5: Variance decomposition at the posterior mean

	Shocks						
Observables	ϵ_a	ϵ_h	ϵ_{yf}	ϵ_j	ϵ_i	ϵ_{jc}	ϵ_v
GDP	0.36	0.04	0.00	0.35	0.04	0.02	0.19
	[0.22, 0.49]	[0.02, 0.06]	[0.00, 0.00]	[0.12, 0.56]	[0.01, 0.07]	[0.01, 0.02]	[0.11, 0.27]
Investment	0.12	0.00	0.00	0.01	0.70	0.00	0.17
	[0.05, 0.18]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.01]	[0.55, 0.85]	[0.00, 0.00]	[0.07, 0.27]
Residential Invest.	0.00	0.46	0.00	0.50	0.00	0.01	0.03
	[0.00, 0.00]	[0.23, 0.72]	[0.00, 0.00]	[0.25, 0.76]	[0.00, 0.00]	[0.00, 0.01]	[0.01, 0.04]
Consumption	0.24	0.00	0.00	0.02	0.07	0.56	0.12
	[0.18, 0.29]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.04]	[0.04, 0.10]	[0.48, 0.62]	[0.09, 0.15]
Real House Prices	0.05	0.00	0.00	0.88	0.01	0.02	0.04
	[0.01, 0.08]	[0.00, 0.01]	[0.00, 0.00]	[0.79, 0.98]	[0.00, 0.02]	[0.00, 0.03]	[0.01, 0.07]

The table reports the theoretical variance decomposition at the posterior mean in percent for the baseline model with migrant human capital in excess of local $\chi = 1.85$. The numbers in brackets are are the 5% and 95% confidence intervals. All observables are defined as per data transformations.

5 A migration shock

An increase in migration is a rise in a country's population and its labour supply. As a result, a positive migration shock, initially at least, reduces the *per capita* value of stocks such as capital, housing and bond holdings. As our calibration assumes that migrants have a higher stock of human capital than locals, the per capita stock of human capital rises in response to a migration shock. Much of the transitional dynamics of the model economy are therefore driven by the reversion of these stocks to their steady-state values following a shock to migration.

Another key driver of the model's dynamics following a migration shock is the response of the real exchange rate or (near-synonymously) the terms of trade. Figure 3, which shows the impulse responses of the model using the mean of the estimated parameters, suggests that the terms of trade, defined as the price of foreign to home-produced goods, appreciate following an unexpected increase in migration. The reason the terms of trade appreciate is that a migration shock raises absorption of home-produced goods. The estimation results suggest that agents have a significant degree of home-bias in both consumption and investment expenditure (the smaller is the openness parameter γ, the greater is home bias), which raises demand for domestically produced goods by more than the demand for imports, and hence leads to an appreciation of the terms of trade. An appreciation of the terms of trade raises the return to domestic factors of production and increases the purchasing power of domestic consumers. The real appreciation, caused by the positive migration shock, thus has a positive wealth effect on consumption.

An increase in migration lowers the per capita physical capital stock. This reduction in capital per capita, along with the appreciation in the terms of trade, has the effect of raising the marginal product of capital. Thus owners of installed capital unambiguously benefit from an increase in migration. The increased return on capital stock raises investment. At the same time, an increase in migration raises the utilisation rate of capital. As Brunow et al. (2015, p. 1030) note, a constant returns to scale technology implies that per capita income declines when labour supply increases are not accompanied by corresponding increases in capital. In our model, however, changes in capacity utilisation partially offset the movements in capital per capita that arise with migration inflows and outflows.

Boubtane et al. (2016) estimate that the relative stock of human capital for migrants into New Zealand is 1.85 times that of the average domestic resident for the 1986-2006 period. Only the United States, with an estimated ratio of 0.97, has a ratio below 1; the remaining countries examined by Boubtane et al. have ratios from $1.01 - 2.87$ (Greece and Ireland respectively). Because the empirical evidence suggests that migrants have a higher stock of human capital than New Zealand locals, we observe an increase in the per capita human capital stock following an increase in migration. As the transitional dynamics are characterised by a reversion to the pre-migration mean, the representative household reduces investment in skill acquisition. Less time spent training, means more time spent on hours worked. As a result, effective hours per capita increase following a rise in migration. The combination of a lower capital stock and an increased supply of effective labour, pushes down the wage rate. On impact, this effect is offset by the appreciation of the terms of trade. After a couple of quarters, the wage rate falls, reverting back to the initial steady state in the medium run. The increase in effective hours plus the increase in capacity utilisation allow output per head to rise in response to a positive migration shock.

In the housing market, the per capital stock of housing is reduced by a sudden increase in migration. Given that migrants have the same preferences over housing and consumption as locals, the demand for new houses as well as the price of housing rises and the return on land increases. The increase in demand for new housing stock stimulates construction activity. Building houses requires land, labour and intermediate goods. Although total effective hours per worker increase, there is some reallocation of labour effort from the goods into the construction sector. Effective hours in the construction sector increase by more than in the goods producing sector. To ensure that the post-migration steady-state is the same as the pre-migration steady state, we assume that the supply of building land is allowed to grow with the population.

GDP is the sum of goods production and construction denoted by the blue line in the top left panel of figure 3. In the estimated model, GDP rises by more than goods production. In summary, an increase in skilled migrants is expansionary for a small open economy. Even though the wage rate falls, per capita consumption, investment and GDP rises. Migration raises the return to stocks of physical capital and land and can temporarily reduce the return to human capital if migrants bring with them higher stocks of human capital. Our business cycle results contrast with the cross-country panel data analysis of Brunow et al. (2015), who find that decadal averages of per capita GDP are unrelated to decadal movements in net migration.

5.1 Does migration drive the business cycle?

Having analysed the dynamics of a migration shock in the model, we now consider whether migration is an important driver of the business cycle. Table 5 presents the variance decomposition at the posterior mean of our estimated model, with the lower and upper limit of the 90 percent Bayesian confidence intervals in square brackets underneath.

Over our sample, the median contribution of the migration shock is 19 percent of the variance of observed GDP per capita. The rest of the variance is accounted for, in roughly equal parts, by the TFP shock and the preference for housing shock. Recall that GDP consists of output of goods as well as housing. Migration is thus one of the main drivers of the variance of New Zealand GDP. For per capita consumption, migration is the third most important driver accounting for on average 12 percent of the variance, behind the consumption preference shock and the productivity shock. For investment, the migration shock accounts for on average 17 percent, which makes it the second most important driver behind the MEI (marginal efficiency of investment) shock. The role of migration shocks for the volatility of the housing market variables is modest, between 4 percent for real house prices and 3 percent for residential investment. The variance of residential investment is split relatively even between the housing sector productivity shock and the demand for housing shock, with a further 3% accounted for by migration. The variance of house prices is largely accounted for by the housing demand shock, which contributes 88% to the variability of real house prices. Migration accounts for 4%, which is more than is accounted for by the housing supply shock.

Given the relatively low degree of trade openness and the ability of the terms of trade to insulate the economy against foreign shocks, it is not surprising that the shock to world GDP has virtually no effect on the variances of our observables.

6 Sensitivity analysis: The relative human capital of migrants

One of the key assumptions of our DSGE model is that, on average, migrants have higher human capital levels than locals. As our data is not informative about this parameter, we calibrated this parameter χ to a baseline value of 1.85, which is the value estimated by Boubtane et al. (2016) for New Zealand for the period from 1986 to 2006. We justified this claim by noting that skilled and entrepreneurial migrants are a large proportion of total migration into New Zealand. Here we re-estimate the model under the assumption that migrants' human capital stock does not differ from that of locals, and explore the contribution that migration shocks then make to the variability of our observables.

Tables 6 and 7 reports the parameter estimates and the variance decomposition for a model where χ has been set to 1. Cancelling out the effects of migration on the stock of human capital does not significantly alter the model's parameter estimates, see Table 6, but does significantly reduces the contribution of the migration shock to the variance of our observables. For per capita GDP, the contribution falls from around 19 percent to 0.2 percent, for residential investment the figure drops from 3 percent to 0 percent. For consumption per capita the migration shock's contribution of the total variance falls from 12% to just 3% and for house prices from 4% down to 1%. Our results thus imply that migration has less of an effect on the business cycle when migrants are closer to the local population in terms of their human capital. Our business cycle results thus cohere with an observation by Dustmann et al. (2005, p. F324), namely that "labour market effects of immigration depend most importantly on the structure of the receiving economy, as well as the skill mix of immigrants, relative to the resident population." Figure 4 illustrates how the contribution of migration shocks varies with the parameter χ. The relationship is U-shaped, with minima approximately at $\chi = 1$, ie, where migrants and locals have equivalent levels of human capital.

7 An SVAR look at the data

Having investigated the business cycle effects of migration via a DSGE model, we now look at the data using a structural vector autoregression (SVAR). As SVARs embody fewer restrictions, we do not necessarily expect to find the exact same dynamics as in the DSGE model. Instead, our focus is on the qualitative effects of a migration shock on the variables in our data set. In this section, we ask whether or not a migration shock in an SVAR is expansionary for the components of GDP, whether it raises residential investment and house prices, and whether it causes the real exchange rate to appreciate. In other words, are the qualitative dynamics of an SVAR comparable with those generated by the estimated DSGE model?

We develop an SVAR from the same observable variables that were used to estimate the DSGE model, but augmented with the real wage and the real exchange rate, both logged and detrended as previously described. We specify the VAR as follows

$$A_0 y_t = A(L) y_{t-1} + u_t. \tag{39}$$

where A_0 is a $k+1 \times k+1$ matrix; y_t is a $k+1$ column vector of variables, including a 1 to account for constants, and $A(L) \equiv A_1 L + A_2 L^2 + \ldots A_p L^p$ denotes a lag polynomial where L is the lag operator, such that $Ly_t = y_{t-1}$. The vector u_t represents the mean-zero, serially uncorrelated exogenous shocks with diagonal variance-covariance matrix Σ_u. The reduced form errors thus have a variance covariance matrix $A_0^{-1}\Sigma_u(A_0^{-1})'$.

Migration shocks are identified through a recursive identification scheme. We treat world GDP as an exogenous variable, ordered first in the causal ordering, followed by per capita migration.[9] Migration shocks are assumed to be uncorrelated with contemporaneous shocks to domestic variables. While we employ a Cholesky decomposition to identify the world GDP and migration shocks,

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[9] The migration process is equivalent to what one would obtain from a VARX model with contemporaneous and lagged world GDP included as exogenous regressors.

Table 6: Estimated parameters values

Parameter	Description	Prior	Mean	Std Dev	Post. Mean	(5%	95%)
α	Share of capital	N	0.330	0.010	0.330	0.313	0.346
α_h	Share of land in housing	N	0.700	0.050	0.612	0.560	0.665
δ	Depreciation rate capital	N	2.500	0.500	2.791	2.011	3.577
η	Frisch elasticity	Γ	2.000	0.750	3.778	2.223	5.294
ces	Intratemp. subst. elasticity	N	1.000	0.250	2.551	2.501	2.590
γ	Openness	β	0.300	0.010	0.338	0.322	0.354
acu	Capacity-U curvature	β	0.500	0.150	0.667	0.477	0.863
ac	Investment adjustment costs	N	4.000	1.500	6.348	4.525	8.173
$\phi^b \times 100$	Bond adjustment costs	Γ^{-1}	1.000	5.000	0.204	0.152	0.253
ρ_a	Persistence tech.	β	0.500	0.200	0.756	0.703	0.808
ρ_{ah}	Persistence housing tech.	β	0.500	0.200	0.714	0.609	0.823
ρ_y	Persistence foreign demand.	β	0.886	0.010	0.887	0.871	0.903
ρ_j	Persistence housing pref.	β	0.500	0.200	0.861	0.806	0.917
ρ_{jc}	Persistence consumption pref.	β	0.500	0.200	0.833	0.785	0.881
ρ_i	Persistence investment-specific	β	0.500	0.150	0.272	0.145	0.397
ρ_v	Persistence migration	β	0.890	0.010	0.890	0.874	0.907
ϵ_a	Std dev. tech.	Γ^{-1}	0.004	1.500	0.030	0.026	0.034
ϵ_h	Std dev. housing tech.	Γ^{-1}	0.005	1.500	0.037	0.032	0.043
ϵ_{yf}	Std dev. foreign demand	Γ^{-1}	0.007	1.500	0.007	0.006	0.008
ϵ_j	Std dev. housing pref.	Γ^{-1}	0.005	0.500	0.533	0.337	0.728
ϵ_i	Std dev. investment-specific	Γ^{-1}	0.005	1.500	0.367	0.247	0.485
ϵ_{jc}	Std dev. consumption pref.	Γ^{-1}	0.004	1.500	0.034	0.030	0.039
ϵ_v	Std dev. migration	Γ^{-1}	0.001	1.500	0.001	0.001	0.001
	Calibrated						
χ	Relative human cap of migrants	1					
$\delta_h \times 100$	Depreciation rate housing	1					
β	Discount rate	1/1.01					
δ_d	Depreciation rate human cap.	0.01					
ϕ_s	Skill accumulation	0.5					
$\bar{j}$	Steady-state j	0.7					
$n + s$	Hours worked + training	1/3					
ξ_m	Share of traded goods in housing	0.1					
H/c	H - C ratio	0.12					

Table 7: Variance decomposition at the posterior mean

			Shocks				
Observables	ϵ_a	ϵ_h	ϵ_{yf}	ϵ_j	ϵ_i	ϵ_{jc}	ϵ_v
GDP	0.46	0.06	0.00	0.35	0.10	0.03	0.00
	[0.28, 0.62]	[0.03, 0.09]	[0.00, 0.00]	[0.13, 0.56]	[0.03, 0.16]	[0.02, 0.04]	[0.00, 0.00]
Investment	0.08	0.00	0.00	0.00	0.88	0.00	0.03
	[0.03, 0.14]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.01]	[0.81, 0.95]	[0.00, 0.00]	[0.01, 0.05]
Res. Investment	0.00	0.56	0.00	0.42	0.00	0.01	0.00
	[0.00, 0.00]	[0.32, 0.81]	[0.00, 0.00]	[0.16, 0.66]	[0.00, 0.01]	[0.00, 0.02]	[0.00, 0.01]
Consumption	0.20	0.00	0.00	0.01	0.11	0.66	0.03
	[0.15, 0.25]	[0.00, 0.00]	[0.00, 0.00]	[0.00, 0.02]	[0.06, 0.15]	[0.59, 0.73]	[0.02, 0.04]
Real House Prices	0.06	0.01	0.00	0.87	0.03	0.03	0.01
	[0.01, 0.10]	[0.00, 0.01]	[0.00, 0.00]	[0.77, 0.98]	[0.00, 0.05]	[0.00, 0.06]	[0.00, 0.01]

The table reports the theoretical variance decomposition at the posterior mean in percent for the baseline model with migrant human capital in excess of local $\chi = 1$. The numbers in brackets are are the 5% and 95% confidence intervals. All observables are defined as per data transformations.

we disregard the exact ordering of the subsequent domestic shocks, since they are not of material importance to our migration analysis. The lack of contemporaneous correlation seems a reasonable identifying assumption given that obtaining a visa or going through the logistics of leaving a job and moving from one country can be a lengthy process.

We use a multivariate Bayesian information criterion (MBIC) to determine the lag structure of the model. Unsurprisingly, given the comparatively strong penalty on the number of parameters and hence the preference for parsimony, the MBIC implies that the reduced form VAR has a single lag.[10]

In our DSGE model we assume that the migration impulse is exogenous to the domestic economy. This assumption may seem a little implausible, since the propensity to migrate should reflect the relative costs and benefits in home and foreign countries (see for example Clark et al. 2007, Mayda 2010, and Hatton 1995). To explore whether domestic pull factors are material explanators of our migration series we conduct a simple Granger-causality test. We focus on the migration equation alone, and consider simple autoregressive processes against single equations that have lags of domestic variables as additional regressors.

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[10] The Hannan-Quinn information criterion also implies a VAR model with one lag, while the Akaike information criterion implies that four lags should be included.

When the migration equation from a VAR(1) is compared to an AR(1) process for migration, a likelihood ratio test cannot reject the restrictions embedded in the AR(1). The dynamics of the migration equation are predominantly affected by its own lags. This block exogeneity assumption is not material to our qualitative results. The impulse responses are virtually identical if one specifies the migration equation as an autoregressive process or as an unrestricted equation from a VAR(1), with feedback from lagged domestic variables. Specifying migration as an exogenous process does, however, have the benefit of making our SVAR model broadly comparable with the reduced form of the DSGE model.[11]

In Figure 5 we report the impulse response shock to migration. The independent and identically distributed migration shock has the same standard deviation as in the DSGE model (0.00056), which of course is propagated via the AR(1) process used to model the migration series. In the long-run this shock corresponds to a cumulative impulse of roughly 0.0053 percent of working age population. This is larger than the simple standard deviation of the working age migration series, but reflects the fact that migration impulses exhibit a strong degree of autocorrelation. The migration shock is associated with a statistically significant increase in consumption, investment, residential investment, and house prices. GDP per capita also increases, but is not significantly different from zero. The VAR impulse response also confirms one of the key transmission mechanisms of a migration shock, namely the appreciation of the real exchange rate associated with a migration shock.

8 Conclusion

Migration shocks matter for the business cycle. Using a dynamic stochastic general equilibrium model of a small open economy estimated on data for New Zealand, we find that migration shocks account for a considerable proportion of the variability of per capita GDP. For the components of per capita GDP, migration shocks matter, but are not the key drivers. Even for residential investment and real house prices, migration shocks are important, but by no means the key driver of the variation in these variables.

An unexpected positive migration shock is found to be expansionary in terms of per capita real

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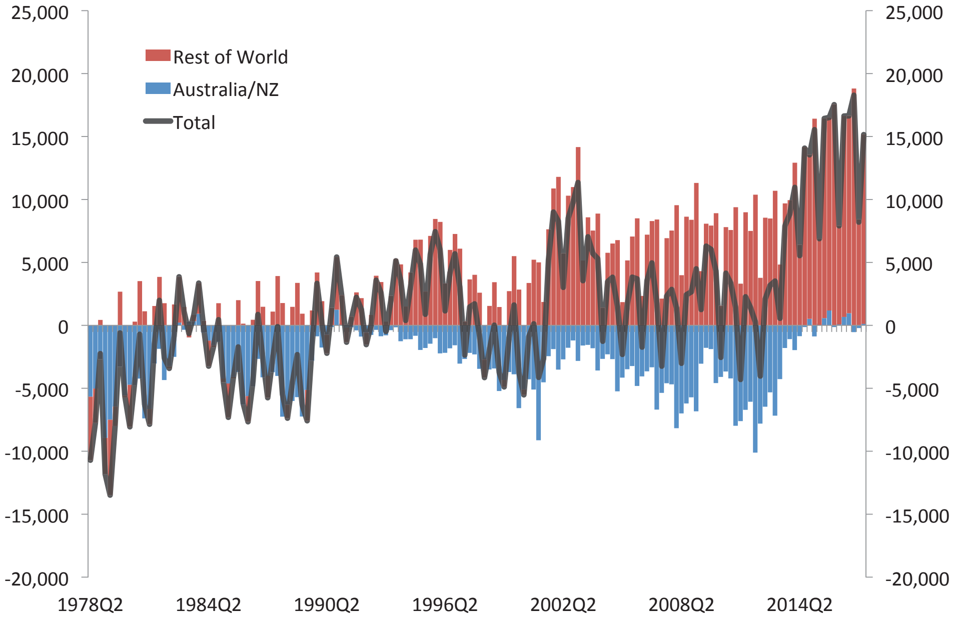
[11] Given that the exogenous shocks in the DSGE model are AR(1) processes the reduced form of the DSGE model corresponds to a VAR(2).

GDP and its components and is associated with an initial appreciation of the terms of trade. As expected, migration benefits the owners of fixed assets such as capital or housing: the returns on these assets rise with an influx of migrants. The return on human capital is also affected by the relative human capital of migrants versus locals. If, as in our case, migrants have an initially higher level of human capital than locals, the real wage, or the return on effective labour falls.

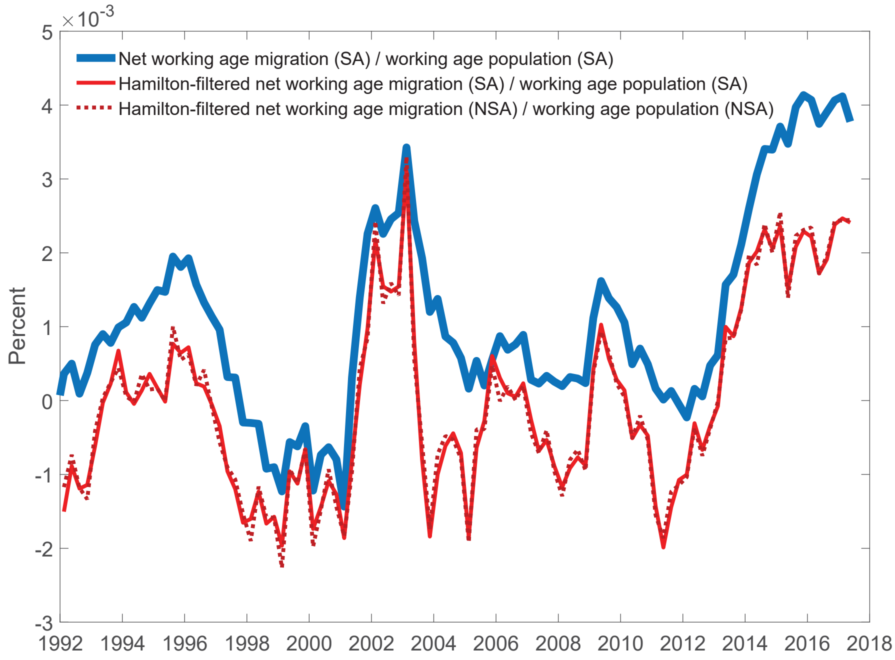
The relative level of human capital of migrants also affects the extent to which migration shocks contribute to the volatility of per capita GDP. We conduct a sensitivity analysis on the relative level of human capital. We find that the impact of migration shocks for the business cycle is much diminished if new migrants and locals have similar levels of human capital. When we assume that migrants have the same level of human capital as locals, migration shocks make only a minor contribution to the variances of per capita GDP and other macro variables.

Figure 1: Net working-age migration flows into and out of New Zealand



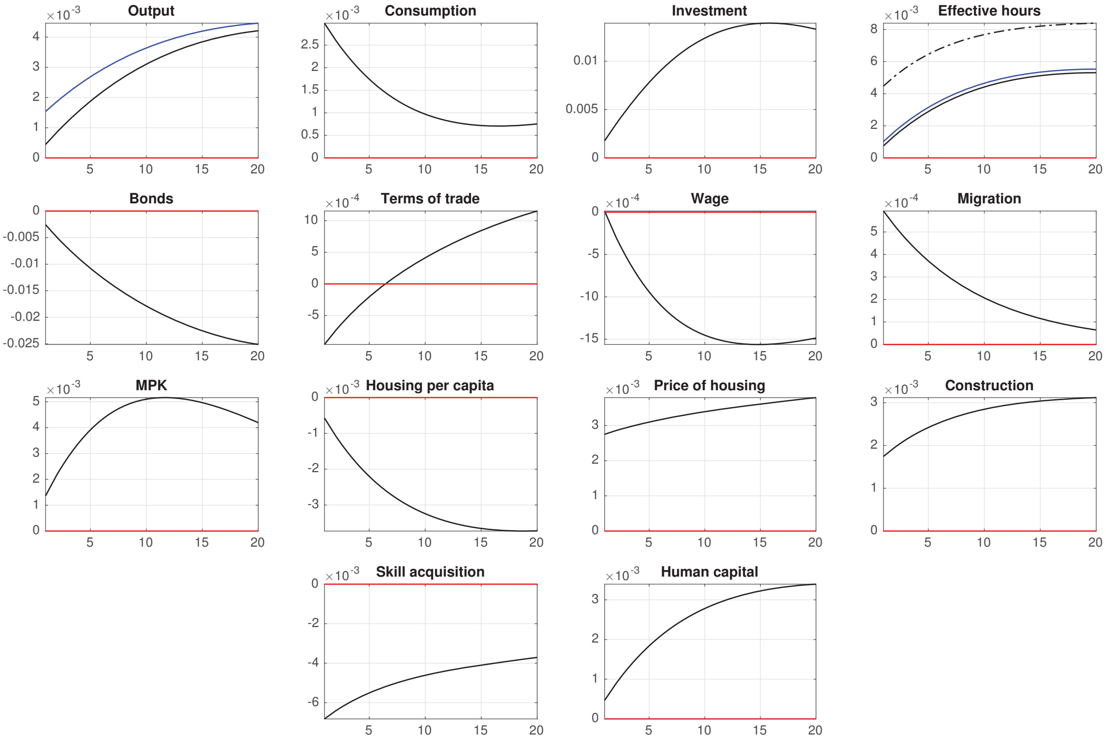
Note: The solid black line denotes non-seasonally adjusted working-age net migration into New Zealand. This figure is split into net migration from New Zealand to Australia (blue bars) and net migration into New Zealand from all countries other than Australia (red bars).

Figure 2: Net working-age migration flows detrended via local linear projections



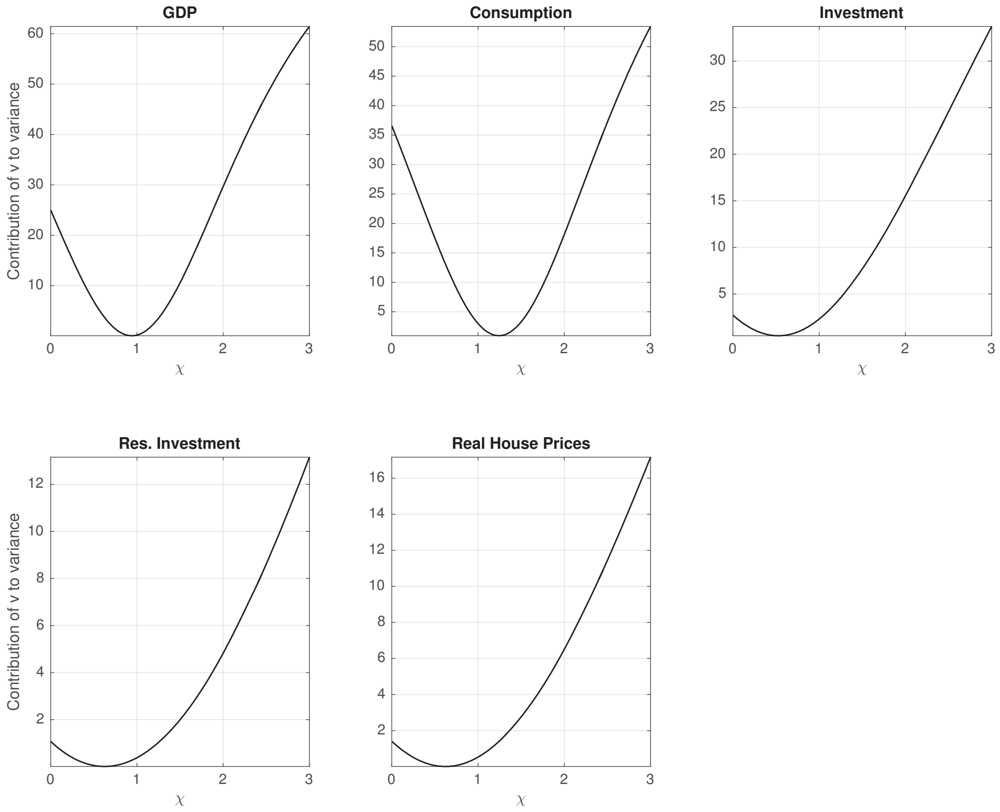
Note: The thick blue line is the net migration working age impulse relative to the size of total working age population on a quarterly basis, seasonally adjusted. The two red lines are the cycles derived from applying the Hamilton local linear projection to the thick blue series and to an equivalent series that has not been seasonally adjusted. These cyclically adjusted series have means of zero by construction.

Figure 3: A migration shock



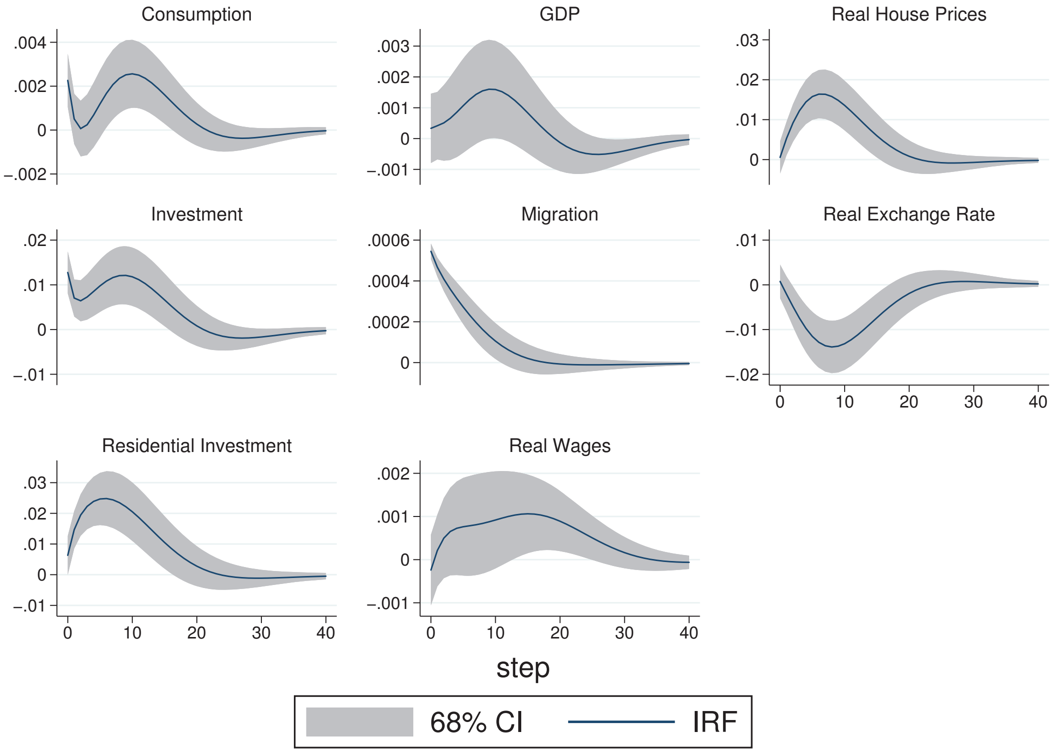
Note: An increase in migration in a small open economy. In the 'output' panel, the blue line denotes GDP, while the black line denotes the log-deviation of home-produced traded goods. In the 'Hours' panel, the blue line denotes total effective hours supplied by households, the black line denotes effective hours devoted to goods production, while the dashed-dotted line denotes effective hours in construction. In the panel GDP growth, the blue line denotes growth of total GDP, while the black line denotes growth of GDP per capita.

Figure 4: The role of migration shocks as a function of χ



Note: This figure reports the variance contributions of the migration shock for different values of the relative human capital parameter χ, migrant capital to local, with all other parameters held constant at the mean posterior values.

Figure 5: A migration shock in a VAR



Notes: An increase in migration in a small open economy. Migration shock in the VAR(1) is identified by a Cholesky decomposition where the filtered world GDP series is ordered first followed by the migration per capita series which is ordered second. All data series are logged and de-trended using the Hamilton (2017) filter, as in Bayesian estimation. The dashed lines are 68% confidence intervals. A decline in the real exchange rate series denotes a real appreciation.

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A Steady State

$$\mu = 1/c \tag{40}$$

$$0 = \phi_0(n+s)^\eta + (1/c)wd \tag{41}$$

$$0 = -\phi_0(n+s)^\eta + \lambda\phi_s\frac{(ds)^{\phi_s}}{s} \tag{42}$$

$$\lambda = (1/c)wn + \beta\lambda\left[\phi_s\frac{(sd)^{\phi}_{s}}{d} + (1-\delta^d)\right] \tag{43}$$

$$1 = \frac{(ds)^{\phi_s}}{d} + (1-\delta^d) \tag{44}$$

$$1 = \beta(1+r) \tag{45}$$

$$\frac{q^H h}{c} = \frac{j}{(1-\beta(1-\delta_h))} \tag{46}$$

$$p^l = \beta\left(p^l + R^l\right) \tag{47}$$

$$\frac{n}{s} = \frac{(1-\beta(\delta_d(\phi_s-1)+1)}{\phi_s\delta_d} \tag{48}$$

$$n+s = 1/3 \tag{49}$$

$$n = \frac{(n+s)\frac{n}{s}}{\frac{n}{s}+1} \tag{50}$$

$$s = (n+s)-s \tag{51}$$

$$\frac{y}{k} = \frac{1/\beta-(1-\delta)}{\alpha} \tag{52}$$

$$\frac{c}{k} = \frac{y}{k} - \delta \tag{53}$$

$$\frac{k}{n} = (\frac{y}{k})^{1/(\alpha-1)} \tag{54}$$

$$\frac{n^y}{n^h} = \frac{y}{k}\frac{k}{c}\frac{c}{h}\frac{1}{\delta_h q^H} \tag{55}$$

$$\frac{n}{n^h} = 1 + \frac{n^y}{n^h} \tag{56}$$