Household Leverage and the Housing Wealth Effect

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Abstract

This paper investigates the effects on consumption of housing wealth, housing leverage, and their interaction, both empirically and theoretically. Empirically, we use microdata from New Zealand to estimate the marginal propensity to consume out of exogenous changes in housing wealth and how it is affected by the household leverage ratio. Our empirical finding suggests a weakening role of leverage on the marginal propensity to consume out of housing wealth. We use a theoretical model to understand mechanisms at work. We show both analytically and numerically that house price dynamics and risk-aversion of household preference matter for the interaction between leverage and the housing wealth effect.

Keywords: Household debt, Housing wealth effect, Leverage, Marginal propensity to consume

JEL Classification: D12, D14, E21, E44, R2

Disclaimer: The views expressed in the paper do not necessarily reflect those of the Reserve Bank of New Zealand, nor the Bank of Canada. Access to the data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975. The results presented in this study are the work of the authors, not Statistics NZ.

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1 Introduction

Understanding the dynamics of household consumption is crucial for modelling business cycles and designing macroeconomic policy. Classic theories of consumption suggest that the wealth plays an important role in determining household spending (See e.g. Fisher, 1930; Friedman, 1957). Housing wealth takes center stage of modern discussion because, on the one hand, housing wealth makes up the lion’s share of household wealth in most advanced economies, so large swings in house prices significantly influence household balance sheets and potentially therefore consumption behavior. On the other hand, the large share of housing wealth comes alongside a large share of housing debts on the liability side of balance sheets, making indebtedness come into play too. Seminal work by Mian, Rao, and Sufi (2013) highlights this linkage of house prices, leverage and consumption during the US Great Recession.

In this paper, we investigate mechanisms through which household leverage affects the housing wealth effect on consumption. The prevalent view in the recent literature is that greater household indebtedness makes consumption expenditure more sensitive to changes in housing wealth, and it is due to mechanisms that involves collateral (borrowing) constraints on household borrowing (see: e.g. Iacoviello, 2005, among other). We argue that the interaction between the leverage ratio and the housing wealth effect depends not only on the behavior of households subject to borrowing constraints, but also the behavior of unconstrained households. As a result, there are many other factors in the model affecting the interaction between leverage and housing wealth effect. In particular, the interaction can be asymmetric to house price dynamics, and house price dynamics interact with risk aversion of household preference. We conduct both empirical and theoretical analysis to explore this issue.

In the first part of paper, we use microdata from New Zealand "Household Economic Survey" (HES) to study the interaction empirically. We focus on how household leverage affects the marginal propensity to consume (MPC) out of housing wealth. HES contains detailed information on household spending, income and loans. We combine HES with regional house price data to address endogeneity issues that arise from our regression analysis. An important issue in studying housing wealth effect is that wealth effects on consumption should be identified only off exogenous shocks. In the canonical life cycle model, consumption spending and wealth accumulation including housing wealth, are simultaneously determined. Households, who for example expect a rapid income growth in the coming years, may spend more and acquire a more expensive house. Therefore, modelling the 'exogenous' component of house

\[1\] We would like to thank Real Estate Institute of New Zealand (REINZ) for providing us with micro house price data.
price changes to households is crucial. To address this problem, we use local house price indices as our measure of exogenous variation in house prices. Therefore, our primary source of identification arises from differential changes in house prices across localities, which is treated as exogenous to household-specific factors, such as preferences and expected income profiles. The estimated coefficient on the interaction term between leverage and housing wealth is negative, suggesting a weakening role of household leverage on the housing MPC. This is true, even after controlling for the life cycle.

Our empirical result is surprising in the light of the findings of Mian, Rao, and Sufi (2013). However, existing US studies mainly focus on the periods after the Global Financial Crisis, during which US housing markets suffered from a severe downturn, while, in the most of our sample period New Zealand house prices were growing. If the effect of the leverage ratio is asymmetric to an increase or decrease in housing wealth, the estimated coefficient will be different.

To further investigate how leverage affects the housing wealth effect, we develop a rich heterogeneous-agent model with housing and collateral constraints. We use the calibrated model to investigate mechanisms that influence the observed interaction between leverage and the MPC out of housing wealth. To gain some intuition, we first employ a simple two-period model to show analytically how the difference between housing MPCs of households with different leverages is effected by various parameters. Besides the loan-to-value ratio, the discount rate, house price process, the interest rate and the risk aversion parameter all matter. We show in a simple example that interaction between leverage and housing MPC can be asymmetric with respect to house price persistence. To examine those mechanisms in the full model, we solve the calibrated model numerically. Using simulated panel data of households, we first replicate regressions in our empirical analysis and then vary model’s parameter to study how they change the estimated coefficient. Numerical results confirm the intuitions from the two-period model. We find that the effect of the leverage ratio on the housing wealth effect turns out to be asymmetric. When house prices decrease, the interaction coefficient becomes less negative than those under increasing house prices. We also show that leverage weakens the housing wealth effect more as households become more risk averse.

Our paper is closely related to the growing literature of housing wealth effects on household consumption. A large housing wealth effect relative to non-housing wealth has been documented by classic studies by Case et al. (2005) and Carroll, Otsuka, and Slacalek (2011). Using aggregate data, the estimated MPC out of housing wealth in these studies range from 3 to 5 cents on a dollar gain in housing wealth. Studies using microdata reveal more detailed picture about the housing wealth effect. For ex-
ample, Campbell and Cocco (2007) use the U.K. Family Expenditure Survey and show that elasticity of consumption to house prices depends on age and tenure types. MPC is large for old homeowners, while it is close to zero for young renters.\footnote{See also other micro studies, e.g. Levin (1998), Juster, Lupton, Smith, and Stafford (2001), Lehnert (2003) and Bostic, Gabriel, and Painter (2005).}

Since the GFC, a new strand of papers has emerged focusing on the role of household leverage in shaping the housing wealth effect on consumption. Dynan (2012) shows that high household debt holds back consumption using household-level panel data in the US. But she didn’t study the interaction between household leverage and MPCs. Mian, Rao, and Sufi (2013) use county and zip code level data to estimate MPC to housing equity shocks. They obtain estimates of MPC in the range of 5 to 7 cents for every dollar change in housing net worth. They also show that consumption responses to negative wealth shocks are stronger in poor and/or highly indebted regions during the Great Recession. This conclusion has been confirmed by Kaplan, Mitman, and Violante (2016) using publicly available data and Baker (forthcoming) using data from an online personal finance website.

Motivated by this new strand of literature, international evidence has been fast accumulating revealing new insights. Fagereng, Natvik, and Yao (2015) use detailed Norwegian household data and find the housing leverage, measured by loan-to-value ratio, amplifies the housing wealth effect by about 19-30 cents. In addition, they show that aggregating household level data into municipality or county levels makes the estimated MPC larger than its micro-level counterpart. Hviid and Kuchler (2017) use a large Danish household panel dataset and document asymmetric MPC out of positive and negative house wealth shocks. Households’ consumption is more sensitive in response to negative housing wealth shocks than to the positive ones. The asymmetric housing wealth effect was also suggested by Engelhardt (1996) and Skinner (1989) \footnote{Skinner (1994) using US microdata. In this paper, we document a different effect of leverage on the housing wealth effect, using New Zealand microdata. We also contribute towards better understanding the interaction between leverage and the housing wealth effect by employing simulations from a rich heterogeneous-agent model. Overall, we conclude that the interaction between leverage and the housing wealth effect is more complex than current understanding in the literature. We show that optimal behavior of unconstrained households matters. This channel involves complex interactions between house price dynamics and household preference, which deserves more research in the future.}

The present paper is organized as follows. Section 2 discusses the data and empirical approach. This is followed by a theoretical analysis in a simple two-period model in Section 3. Section 4 develops a rich
2 Empirical Analysis

This section first describes the data used for empirical analysis and later explains the econometric methods used to answer our research questions.

2.1 Data Description

The Household Economic Survey (HES) of Statistics New Zealand collects comprehensive data on household residents living in permanent dwellings. HES covers multiple aspects of household economics including highly disaggregate expenditures, income, and loans for every individual in the household. The survey also covers demographics, house ownership status, and house value. The data are stratified by different benchmarks including age, sex, population per region, two adults and non-two adult households, and people of Maori ethnicity. This guarantees proper weighting of households and a high degree of comparability along time since the data are cross sectional rather than longitudinal. Data are collected along one-year waves extending from July to June.

We report the details about our data used in regressions in Appendix (A)

2.1.1 Summary statistics

Table A in Appendix (A) reports the mean of main variables in our regression. We first show them from the full sample and then break down in each waves. As our later analysis will focus mainly on the households that own their homes (i.e. not renters), we only report the statistics with respect to homeowners in the table. The age and the household size of homeowners are stable across waves. Age of the head of households is slightly increasing as the population is aging. Over time, expenditures increased substantially, along with incomes. However, during the same period of time, the increase in house prices resulted in a significant rise in household debt as mortgages constitute the main share. The income growth lagged behind the increase in debt over time as the upward trending DTI suggests. In the table, the share of debt to the house value seems low compared to LTV at the time of origination, this is because that our LTV is calculated at the time of survey. It is higher at the origination, as new buyers have not started servicing their debt.

Table 6 in Appendix (A) breaks down homeowners into mortgagors and outright owners. Owners
with mortgage tend to be younger than outright owners, who are closer to the age of retirement. Mort-
gagors also have more people in the household (their children), earn higher income, and have higher
total ex-housing spending. In per capita terms, however, outright owners still have higher income and
expenditures. This is mostly the case because outright owners pay lower debt service, and have higher
wealth. Owners with mortgage generally own cheaper houses as they have not purchased them long
enough to appreciate in value. All these observations seem to suggest that mortgagors in the HES are
typical young family and first-home buyers, while outright owner tend to be old couple living in their
existing home whose value have been appreciated over time. Interestingly, for outright homeowners the
average debt is still around 45,548 NZD, which indicates that they might have a secondary home with
a mortgage to pay down, which is not explicitly reported in the data. Because we don’t have the value
of secondary homes that a household owns, in the regression, we try to further limit our sample to those
who only own one home.

2.2 Empirical approach

The HES data is repeated cross-sectional, as a result, we set up the baseline regression equation as
follows:

\[ \log(C_i) = \beta_0 + \beta_1 \log(HP_i) + \beta_2 \log(Y_i) + \beta_3 Z_i + u_i, \]  

where

\( C_i \): consumption expenditure ex housing

\( HP_i \): house value

\( Y_i \): disposable income

\( Z_i \): age, age^2, Highest education of HH head,

HH Composition, Number of persons,

Number of employed, Maori, Dummies for TA

wave dummies.

If \( \log(HP_i) \) is truly exogenous, we can interpret the estimated coefficient \( \beta_1 \) as the MPC out of housing
wealth. However, with cross-sectional data we cannot control all possible household characteristics, which
matters for both consumption expenditure and housing wealth of the household. Estimating \( \beta_1 \) directly
using HES data would most likely make the empirical results subject to endogeneity problems. For this reason, we replace $\log(HP_i)$ from the HES by the average housing sale prices at the area units (AU) level.\(^3\) We calculate the mean sale price of three-bedroom residential houses for each AU and each year between 2006 and 2016. We then use the address information and interview years in the HES to match each household to the corresponding mean housing sale price in the AU and for the same year. This makes our cross-sectional regression less vulnerable to endogeneity issues. For example, an individual household’s high-income expectation would unlikely affect the average housing sale price in an AU, unless it is driven by a common regional economic growth, which is supposed to be captured by the regional dummies in the regression equation. As stated above, all regressions control for income and a wide range of household characteristics, such as age, education, household composition, ethnicity and year dummies. However, there is no reason to believe that MPC should be a constant in the economy, therefore we also run regressions allowing interactions between MPC with age, tenure types and in particular the leverage of the household in the further empirical analysis. Because the HES doesn’t report the total housing wealth that a household possesses. We calculate LTV only for those who own exactly one property.\(^4\)

### 2.3 Empirical results

#### 2.3.1 Baseline results

Table 2.3.1 shows the estimation results for the baseline regression, for several specifications. In specification (i), we report the estimates based on the HES house prices described in Section 2. The estimated coefficient on house value, $\beta_1$, is 0.08 and it is statistically significant. A 1 percentage increase in housing wealth is associated with a 0.08% increase in consumption expenditure. In column (ii), we report the estimate based on house prices at the AU level.

The estimated MPC using AU prices is almost two times larger than the estimate using HES housing wealth. As we discussed before, the regression based on HES housing value might suffer from severe endogeneity problems due to omitted unobservable household characteristics. Comparing these two columns gives us a sense of biases that are related to those unknown endogeneity issues. Given that, in the HES sample, the average household annual consumption spending excluding housing-related expenditures is 42,690 NZ dollars and the average housing sale price at the AU level is 386,137 NZ dollars. In NZ dollar

\(^3\)Area units level is roughly comparable with zip-code level in the US. We also tried out different geographical aggregations; our results are not sensitive to the changes. Results are available upon request.

\(^4\)We control this, by excluding households who are reported to have rental income or have mortgages on secondary properties.
Table 1: Baseline regression results on the MPC out of housing wealth for homeowners

<table>
<thead>
<tr>
<th></th>
<th>i</th>
<th>ii</th>
<th>iii</th>
<th>iv</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total Exp.</td>
<td>Total Exp.</td>
<td>Non-durable</td>
<td>Durable</td>
</tr>
<tr>
<td>Housing wealth</td>
<td>0.08***</td>
<td>0.17***</td>
<td>0.15***</td>
<td>0.22***</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.05)</td>
</tr>
<tr>
<td>Income</td>
<td>0.40***</td>
<td>0.40***</td>
<td>0.36***</td>
<td>0.60***</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.08)</td>
</tr>
<tr>
<td>Regional dummy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Time dummy</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Household chara</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>5134</td>
<td>4644</td>
<td>4644</td>
<td>3792</td>
</tr>
<tr>
<td>Adj-$R^2$</td>
<td>0.56</td>
<td>0.57</td>
<td>0.58</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Notes: All regressions include a matrix of control variables listed in Equation (1). The first two columns are regressions on total ex. housing expenditures, while the specification iii and iv are for durables and non-durables expenditures, respectively. In Column i, we use HES house price, while in Column ii we use regional house price at the Area Unit (AU) level. The number of observations is not identical as we could not perfectly match the addresses reported in HES and the regional house price data. The last column of durables has fewer observations, because not all households reported durable non-housing expenditures within the two-week period of the survey. The number of observations is rounded up or down randomly to a multiple of three in compliance with Statistics New Zealand rules.

terms, the average MPC out of a one-dollar increase in housing wealth is around 1.9 cents. In columns (iii) and (iv), we separate ex-housing consumption expenditure into durable and nondurable spending. Overall, durable expenditure responds stronger in magnitude to changes in income and housing wealth than non-durable spending. This is consistent with findings from Mian, Rao, and Sufi (2013), where they use only auto purchases as proxy for durable spending and some sub-categories of credit card sales as the measure of non-durable expenditure.

2.3.2 The role of leverage

In this sub-section, we study how leverage affect the MPC out of housing wealth. We allow continuous measures of the household leverage to interact with housing wealth. The household leverage is measured by the loan-to-value ratio at the household level. In the regression, we allow the leverage ratio to interact with housing wealth, so that the coefficient $\beta_2$ is the key estimate of interest, capturing how leverage affects MPC out of housing wealth.

\[
\log(C_i) = \beta_0 + \beta_1 \log(HP_i) + \beta_2 LTV_i + \beta_3 LTV_i \ast \log(HP_i) + \beta_4 \log(Y_i) + \beta_5 Z_i + u_i, \tag{2}
\]

where $LTV_i$ denotes the loan-to-value ratio.

Table (2.3.2) summarizes empirical results from regression (2). In Specification i, we only include the
leverage ratio as a new independent variable. Its estimated coefficient appears to be negative and highly significant. It suggests that an increase in LTV by one reduces consumption spending of borrowers by 19%. This result confirms the finding, documented by Dynan (2012), who argues that high household debt holds back consumption expenditure after the GFC.

In specification (ii), we allow the leverage ratio to interact with house prices. This setting allows a nonlinear MPC out of housing wealth conditional on the leverage ratio. Interestingly, the estimated coefficient on the interaction term becomes negative, statistically significant at the 10% level, but the coefficient on the leverage ratio turns positive. However, a closer look at the correlation between these two independent variables shows that these two covariates are highly correlated (0.997). As a result, associated coefficients are imprecisely estimated. Although the magnitude of estimates might be imprecise, the sign of those coefficients are quite interesting. The negative sign of interaction coefficient suggests that, at the household level, leverage weakens the MPC out of housing wealth.

**Figure of Share of high LTV should be here**

To check the robustness of this finding, in Specification(iii), we add a three-way interaction term between age, LTV and housing wealth. The idea of this specification is to check if our estimate is driven by the life cycle pattern. In Figure (XX), we plot the share of households holding a high leverage ratio conditional on age from the HES data. Leverage is systematically high for younger compared to older households. If the housing MPC is also systematically correlated to the life cycle, our interaction term in Column (ii) will pick up this life cycle effect as well. The empirical result shows a small but positive

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>Log non-housing expenditure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>i</td>
</tr>
<tr>
<td>Housing</td>
<td>0.14*** (0.04)</td>
</tr>
<tr>
<td>LTV</td>
<td>−0.19*** (0.05)</td>
</tr>
<tr>
<td>LTV*Housing</td>
<td>− (0.10)</td>
</tr>
<tr>
<td>Age<em>LTV</em>Housing</td>
<td>− (0.00)</td>
</tr>
<tr>
<td>Controls</td>
<td>Yes</td>
</tr>
<tr>
<td>Obs</td>
<td>1853</td>
</tr>
<tr>
<td>Adj. $-R^2$</td>
<td>0.552</td>
</tr>
</tbody>
</table>

Note: These regressions are based on mortgagors only. All regressions include the full set of control variables listed in Equation (1). Number of observations is rounded up or down randomly to a multiple of three in compliance with Statistics New Zealand rules.
estimate, suggesting that the spending of older households will be more sensitive to changes in housing
wealth, when having a higher leverage. More importantly, after controlling this life cycle effect, the
interaction between leverage and housing wealth is still negative with the same magnitude. Last, we
also run a regression without the level of LTV as a regressor in Column (iv). This is motivated by the
collinearity issue between the two covariates. Column (iv) shows that once the collinearity is removed
from the regression, both interaction terms become more statistically significant and the coefficient to
the leverage effect is still negative.

2.3.3 Discussion

We find that the interaction coefficient between leverage and housing wealth is negative. The negative
estimate suggests that households with higher leverage ratios are less sensitive to exogenous variations
in house prices. This result strikingly contrasts the well-known finding of Mian, Rao, and Sufi (2013)
who show that consumptions spending responding to negative housing wealth shocks was stronger in
highly indebted regions during the Great Recession after 2008. This conclusion has also been confirmed
by other studies such as Kaplan, Mitman, and Violante (2016) and Baker (forthcoming). However, we
argue that the interaction between the leverage ratio and the housing wealth effect should in principle
depend on many factors, such as preference, life cycle and even house price dynamics. For example, US
studies mainly focus on the periods after the GFC when the US housing markets suffered from a severe
downturn, while, in the most of our sample periods in New Zealand data, house prices were growing.
If the effect of the leverage ratio is asymmetric in terms of how borrowers’ consumption responding to
increase or decrease in housing wealth, the estimated coefficient can be different.

To further investigate how leverage affects the housing wealth effect, in the next section, we develop
a heterogeneous-agent model with housing and collateral constraints. We will use the calibrated model
to investigate potential drivers of the observed interaction between the MPC out of housing wealth and
the leverage ratio.
3 Intuitions from a two-period model

Before exploring the fully fledged heterogeneous-agent model with housing and collateral constraints, we now turn to a simplified version of the model and derive an analytical result that helps us understand how the housing MPC can differ across borrowers with different leverages. We should show analytically how the MPC out of housing wealth depends on many structural features of the model, including collateral constraint, the interest rate, risk aversion and house price dynamics. Of particular interest we provide a characterization of when the difference in MPC out of housing wealth between high and low leverage households might become negative, rather than the more ‘usual’ positive value.

3.1 Two-period model

Consider a household who faces the following problem:

$$\max_{C_1, C_2, A_1} u(C_1) + \beta u(C_2)$$

subject to

$$A_0 = C_1 + A_1$$  \hspace{1cm} (3)
$$p^h_t H + A_1 R = C_2$$  \hspace{1cm} (4)
$$A_1 \geq -\mu_V p^h_1 H$$  \hspace{1cm} (5)

where $A_0$ is the initially endowed asset, differing across agents. $A_1$ is the asset chosen for period 2, which pays a gross return $R$. $H$ is illiquid housing asset, which is evenly distributed among all agents. $p^h_t$ is the house price in period $t$. Agents have CRRA utility $u(C) = \frac{C^{1-\rho}}{1-\rho}$. We abstract from income, so agents in this model use liquid asset $A$ to smooth their consumption between the two periods.

Conditions (3) and (4) are the budget constraints of the two periods. In the first period, agents make saving or borrowing decision in terms of liquid asset. When borrowing, it is subject to the borrowing constraint (5). Illiquid housing asset is used as collateral, so $\mu_V p^h_1 H$ determines the maximum borrowing and $\mu_V$ is the loan-to-housing value cap. In the second period, the household simply consumes the total wealth.
The household problem can be rewritten as

$$\max_{A_1} u(A_0 - A_1) + \beta u(p^h_2 H + A_1 R) + \lambda [A_1 + \mu V p^h_1 H]$$

where $\lambda$ is the Lagrange multiplier. The FOC are given by

$$-u'(C_1) + \beta u'(C_2)R + \lambda = 0,$$
$$\lambda [A_1 + \mu V p^h_1 H] = 0.$$

Depending on whether (5) is binding or not, there are two cases.

- Case 1: $A_1 > -\mu V p^h_1 H$ and $\lambda = 0$

  When the borrowing constraint is not binding, the Euler equation,

  $$u'(C_1) = \beta u'(C_2)R,$$

  implies

  $$C^*_2 = \Psi C^*_1,$$

  where $\Psi = [\beta R]^\frac{1}{\rho}$.

  We can then derive

  $$A^*_1 = \frac{\Psi A_0 - p^h_2 H}{\Psi + R},$$
  $$C^*_1 = A_0 - \frac{\Psi A_0 - p^h_2 H}{\Psi + R}.$$

- Case 2: $A_1 = -\mu V p^h_1 H$ and $\lambda > 0$

  When the borrowing constraint is binding, period one consumption is given by

  $$\bar{C}_1 = A_0 + \mu V p^h_1 H.$$

There should be a cut-off $\bar{A}_0$ such that $\bar{C}_1(A_0) < C^*_1(A_0)$ if and only if $A_0 < \bar{A}_0$, where

$$\bar{A}_0 = \frac{[p^h_2 - (\Psi + R)\mu V p^h_1]H}{\Psi}.$$
We are now ready to prove our main analytical result.

**Proposition 1.** In this two-period model, the difference between households’ marginal propensities to consume out of housing wealth is given by the following equation:

\[
\frac{d\bar{C}_1}{dp_1} - \frac{dC^*_1}{dp_1} = \left[ \mu_V - \frac{dp_2}{dp_1h} \frac{1}{\Psi + R} \right] H. \tag{6}
\]

**Proof.** An asset-poor (or highly leveraged) agent \((A_0 < \bar{A}_0)\) will be constrained in consumption, and the marginal effect of house price on current consumption is simply

\[
\frac{d\bar{C}_1}{dp_1} = \mu_V H.
\]

By contrast, for an asset-rich (or less leveraged) agents \((A_0 > \bar{A}_0)\), the corresponding marginal effect on consumption is

\[
\frac{dC^*_1}{dp_1} = \frac{dp_2}{dp_1h} \frac{H}{\Psi + R},
\]

Hence the relative magnitude of the marginal effects \(\frac{d\bar{C}_1}{dp_1} \) and \(\frac{dC^*_1}{dp_1} \) is

\[
\frac{d\bar{C}_1}{dp_1} - \frac{dC^*_1}{dp_1} = \left[ \mu_V - \frac{dp_2}{dp_1h} \frac{1}{\Psi + R} \right] H.
\]

\[ Q.E.D. \]

Following Equation (6), the relative magnitude of housing MPCs between highly leveraged versus less leveraged households depends on a range of model’s parameter. In particular, \(\mu_V\) captures the borrowing constraint effect. A higher \(\mu_V\) makes MPC of constraint households larger. Moreover, optimal behavior of unconstrained households matters too, which is captured by the second term in the bracket. In the following, we focus on the role played by the persistence of house price dynamics \(\frac{dp_2}{dp_1h}\) and the risk aversion parameter \(\rho\).

### 3.2 Factors that also matter: House price dynamics

The persistence of house price plays an important role. If \(\frac{dp_2}{dp_1h}\) is a negative or a small positive number, then highly leveraged households have a relatively higher MPC w.r.t. the current house price. However, if \(\frac{dp_2}{dp_1h}\) is positive and big, then highly leveraged households can have a lower MPC w.r.t. to \(p_1\).
The intuition of this result is that future house price appreciation leads to a higher lifetime income, increasing agents’ incentive to consume today. However, only agents whose borrowing constraint is not binding currently can fully smooth consumption by borrowing from future income or by reducing savings. Constrained households cannot increase current consumption by borrowing against future windfall.

\[ dp_1 > 0, \quad dp_2 = 0 \]
\[ dp_1 > 0, \quad dp_2 > 0 \]
\[ \Delta \bar{C}_1 > \Delta \bar{C}^*_1 = 0 \]
\[ \Delta \bar{C}^*_1 > \Delta \bar{C}_1 \]

Figure 1: Effects of house price appreciation on current consumption

Figure 1 illustrates this intuition. In case (a), the house price appreciates but is not persistent. The unconstrained household does not need to adjust their consumption as it is already optimal. The constrained household, however, will choose to raise current consumption as a result of the relaxed borrowing constraint. Hence, the MPC is larger for constrained households. In case (b), the house price appreciation is persistent. The unconstrained household chooses to increase current consumption as a result of the relaxed wealth constraint. The constrained household would like to fully smooth consumption too but is constrained by the borrowing constraint. Hence, the MPC is larger for unconstrained households in this case.

3.3 Factors that also matter: Risk aversion

We now study the effect of the risk aversion parameter \( \rho \). Taking derivative of Equation (6) w.r.t. \( \rho \) yields

\[
\frac{d}{d\rho} \left[ \frac{d\bar{C}_1}{dp_1^h} - \frac{d\bar{C}^*_1}{dp_1^h} \right] = -\frac{dp_2^h}{dp_1^h} \frac{H\Psi}{(\Psi + R)^2} \rho^2 \ln [\beta R] 
\] (7)
Interestingly, the sign of the RHS depends on the magnitude of $\beta R$ and $dp_2^h/dp_1^h$. When $dp_2^h/dp_1^h > 0$ and $R > \frac{1}{\beta}$, then a higher $\rho$ implies a smaller $\frac{dC_1}{dp_1^h} - \frac{dC^*_1}{dp_1^h}$. The idea is that, when future house price and returns to saving are both high, an unconstrained agent has an incentive to increase current consumption relative to consumption in the later period. This consumption-smoothing incentive is stronger when agents are more risk averse. As a result, a higher $\rho$ implies that $\frac{dC^*_1}{dp_1^h}$ is large relative to $\frac{dC_1}{dp_1^h}$.

4 Model

We develop a life-cycle model in which agents make decisions to save/borrow using a combination of housing, debt, and financial assets. Housing is desirable as it generates a flow of housing-consumption which agents value, not because it gives a different return to financial assets. We are interested in both which households are affected by the Macroprudential regulations and how it changes their individual marginal propensities to consume out of housing wealth and out of income. The model is partial equilibrium in terms of housing and financial markets and does not contain aggregate shocks. Our model closely follows that of Fagereng, Natvik, and Yao (2015), and is related to the general equilibrium approach of Kaplan and Violante (2014). Bajari, Chan, Krueger, and Miller (2013) structurally estimate a similar life-cycle model on US PSID (Panel Survey of Income Dynamics) data and find it performs well in capturing housing demand.\footnote{Their model has less demographics than ours, no permanent income shocks (just deterministic profile and transitory income shocks), transaction costs only when buying (not selling) a house, and does not allow any borrowing for non-homeowners. They find the transaction cost of buying and the leverage restrictions (deposit requirements) for mortgages on buying (and owning) a home are important in matching the data on housing demand decisions.}

4.1 Households

The economy consists of a continuum of agents (households) of unit mass. Agents are born with age $a_0$ and live a maximum of $A$ periods.\footnote{We calibrate age to be between $a_0 = 27$ and $A = 90$}. At each age $a$, agents face a risk of death and the conditional survival probability is $p_a^S$. Agents derive utility from consumption and bequests.

Consumption takes two forms: housing consumption and non-housing consumption. Agents get utility from both with a constant elasticity of substitution between the two:

$$\hat{C}_a = \left[ \alpha_a^{1/\theta} C_a^{\theta-1} + (1 - \alpha_a)^{1/\theta} S_a^{\theta-1} \right]^\frac{\theta}{\theta-1}$$

Here $\theta$ is the elasticity of substitution, $C_a$ is non-housing consumption, and $S_a = \zeta H_a$ is the flow of
housing-consumption. $H_a$ is the stock of Housing.

The weight on non-housing consumption depends on the household composition and thus varies with age. We assume,

$$\alpha_a = \alpha \exp \left( f_{\text{adult}} N_a^{\text{Adults}} + f_{\text{child}} N_a^{\text{Children}} \right)$$

(9)

with the normalization that $\alpha_a = \alpha$, where $\alpha$ is the initial weight on non-housing consumption. $N_a^{\text{Adults}}$ and $N_a^{\text{Children}}$ are the number of adults and the number of children in the household at age $a$; $f_{\text{adult}}$ and $f_{\text{child}}$ capture their weights in non-housing consumption.\(^7\)

Agents’ period-utility function over consumption is given by

$$u(\tilde{C}_a) = \frac{\tilde{C}_a^{1-\rho}}{1-\rho}, \quad \rho > 1$$

(10)

On death, which occurs with probability $1 - p_a^S$, agents derive utility from leaving a bequest,

$$u^b(W_{a+1}) = \varphi \frac{W_{a+1}^{1-\rho}}{1-\rho}$$

(11)

where $W_{a+1} = H_{a+1} + A_{a+1}$ is wealth upon death and $\varphi$ is the relative weight with which agents value bequests.\(^8\) Each agent maximizes its expected discounted utility from consumption and bequests,

$$u(\tilde{C}_a) + E_{a_0} \left[ \sum_{a=a_0+1}^A \beta^{a-a_0} \left( \prod_{a_j=a_0+1}^{a-1} p_{a_j}^S \right) \left[ u(\tilde{C}_a) + (1 - p_a^S) u^b(H_{a+1} + A_{a+1}) \right] \right]$$

(12)

where $\beta$ is the discount factor.

**Income Process**

Households income follows a combination permanent-transitory process:

$$Y_a = P_a \Xi_a$$

$$P_a = \Gamma_a P_{a-1} \Phi_a$$

(13)

where $Y_a$ is after-tax income, $P_a$ is the permanent component of income, and $\Xi_a$ is the transitory

\(^7\)Many alternative equivalence measures exist; Kaplan (2012) describes five other commonly used approaches.

\(^8\)Note that this differs from Fagereng, Natvik, and Yao (2015) who include income from period immediately after death as part of the bequest when calculating warm glow. Notice also that this implicitly imposes that $H_{a+1} + A_{a+1} \geq 0$ once you reach the age where your conditional survival probability drops below one (as otherwise the warm-glow from $H_{a+1} + A_{a+1} < 0$ would be negative infinity; or more precisely undefined).
component of income. $\Gamma_a$ is the deterministic component of permanent income common to all households, and $\Phi_a$ is the permanent shock to income. We assume that both the transitory and permanent shocks are log-normally distributed,

$$
\xi_a = \log \Xi_a \sim N\left(-\frac{1}{2}\sigma_{\xi,a}^2, \sigma_{\xi,a}^2\right)
$$

$$
\phi_a = \log \Phi_a \sim N\left(-\frac{1}{2}\sigma_{\phi,a}^2, \sigma_{\phi,a}^2\right)
$$

where $\sigma_{\xi,a}^2$ and $\sigma_{\phi,a}^2$ are the age-dependent variances of transitory and permanent shocks, respectively. Under these assumptions both $E(\Xi_a) = 1$ and $E(\Phi_a) = 1$.

Renters and Homeowners

Households can be renters or homeowners. They also make decisions about moving and house size. Renters can decide to remain renters or become homeowners in the next period. Homeowners can become renters, stay in their current house, or buy another house to move into in the next period. We denote the five possible types of movements between renters and homeowners as $rr$, $rh$, $hr$, $hh$ and $hh'$ respectively. We assume that moving out of or into rented housing has no cost and that changes in owner-occupied housing imply a transaction cost. In particular, we assume that there are proportional transaction costs $\kappa_p$ and $\kappa_s$ that accompany housing purchase and sale.

Budget Constraints

When renters decide to remain renters for one more period, they allocate consumption between non-housing expenditure $C_a$ and housing service $S_a$ in the current period. Their intertemporal budget constraint is

$$
A_{a+1} = (1 + r)A_a + Y_a - C_a - S_a,
$$

where $A_a$ is assets at age $a$, $r$ is the interest rate (which will be different for borrowers and lenders). If renters decide to become homeowners, they must finance their housing purchase in addition to their current consumption:

$$
A_{a+1} = (1 + r)A_a + Y_a - C_a - S_a - (1 + \kappa_a)H_{a+1}.
$$

Homeowners enjoy their housing-consumption, and if they do not move, all of their expenditure at the age $a$ is non-housing expenditure. Moving introduces housing transactions to homeowners budget constraint. For instance, a homeowner who decides to become a renter ($hr$) sells her house, but during
the current period she still enjoys the service flow from her current house:

\[ A_{a+1} = (1 + r)A_a + Y_a + (1 - \kappa_p)H_{a+1} - C_a. \]

**Borrowing**

The borrowing rate \( r_b \) is higher than the risk free interest rate \( r_l \). There are three types of constraints. First, there is unsecured borrowing, wherein households are able to borrow up to a certain amount of their permanent income

\[ A_{a+1} \geq -\mu_{PermY} P_a. \]

Second, there is a loan to value constraint

\[ A_{a+1} \geq -\mu_{LVR} R^h_a H_{a+1}. \]

Third, there is a loan to income constraint

\[ A_{a+1} \geq -\mu_{PV} PV_a, \]

where \( PV_a = E_t \left[ \frac{Y_{a+1}}{1+r_b} + \ldots + \frac{Y_A}{(1+r_b)^{A-a}} \right] \) is the present value of expected income in the future discounted at the borrowing rate. With respect to a households end-of-period assets, the loan to value constraint requires that debt cannot exceed a certain fraction of its current housing value, while the loan to income constraint requires that debt not exceed a certain fraction of the households expected future income. Combining these three constraints we require that whichever is the tighest constraint must bind,\(^9\) giving

\[ A_{a+1} \geq \Lambda = \min(\mu_{PermY} P_a, \mu_{LVR} R^h_a H_{a+1}, \mu_{PV} PV_a) \]

**Households Optimization Problem**

\(^9\)This is needed as otherwise households approaching the end of their life prefer to continue owning their house and simply borrowing against it. This is the better option financially as a slight decrease in house size involves incurring the transaction costs of selling and buying a slightly smaller house, which are imposed on the entire value of the house. While keeping the larger house and borrowing against it simply involves paying interest on the ‘difference’. Without a binding present-value of income constraint on borrowing households would always choose to do this towards the end of their lifetimes.
We can summarize all of the above in terms of the households optimization problem,

\[
\max_{\{C_a, S_a, H_{a+1}, A_{a+1}\}_{a_0}} u(\tilde{C}_{a_0}) + E_{a_0} \left[ \sum_{a=a_0+1}^{A} \beta^{a-a_0} \left( \prod_{a_j=a_0+1}^{a-1} p_{a_j}^S \right) \left[ u(\tilde{C}_a) + (1 - p_a^S)u^b(H_{a+1} + A_{a+1}) \right] \right]
\]

subject to,

\[
C_a = \begin{cases} 
(1 + r)A_a + Y_a - A_{a+1} - S_a & \text{rr} \\
(1 + r)A_a + Y_a - A_{a+1} - S_a - (1 + \kappa_p)H_{a+1} & \text{rh} \\
(1 + r)A_a + Y_a - A_{a+1} + (1 + \kappa_s)H_a & \text{hr} \\
(1 + r)A_a + Y_a - A_{a+1} + (1 + \kappa_s)H_a - (1 + \kappa_p)H_{a+1} & \text{hh} \\
(1 + r)A_a + Y_a - A_{a+1} & \text{hh} \end{cases}
\]

\[
r = \begin{cases} 
 r_l & \text{if } A_a \geq 0 \\
 r_b & \text{if } A_a < 0 \end{cases}
\]

\[
A_{a+1} \geq A = -\min(\mu_{Perm}^y P_a, \mu_{LVRP}^h H_{a+1}, \mu_{P} PV_a)
\]

The only distinction between borrowing and saving financial assets in our model is their interest rate. When assets, \(A_a\), are negative, households are in debt; when \(A_a\) is positive, households hold financial assets. Both debt and financial assets are liquid in the sense that households can run them up or down without cost, subject to the constraints. The model does not distinguish between debt that is secured against housing (mortgage debt) and other kinds of debt.

4.2 Calibration

In the baseline model \(p_H\) is simply normalized to one. All parameter values are simply taken from literature, mainly Fagereng, Natvik, and Yao (2015). They are presented in Table 3.

We are presently part-way through recalibrating all the parameters for New Zealand. Those that have been recalibrated are now described, both how they were calibrated and their New Zealand values. For now however the model results are not based on any of the New Zealand values and remain those presented in Table 3.

The conditional survival probabilities are taken from the New Zealand Population Period Life Tables 2012-14 (New Zealand Statistics); the data are gender-specific and we create survival rates that depend only on age by using age-specific population weights for fractions of population that are male and female.
Table 3: Parameter values for the model economy

<table>
<thead>
<tr>
<th>Life cycle</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial age</td>
<td>$a_0$</td>
<td>27</td>
</tr>
<tr>
<td>Final age</td>
<td>$A$</td>
<td>90</td>
</tr>
<tr>
<td>Bequest weight</td>
<td>$\varphi$</td>
<td>12.3</td>
</tr>
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<table>
<thead>
<tr>
<th>Preferences</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount rate</td>
<td>$\beta$</td>
<td>0.93</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\rho$</td>
<td>1.20</td>
</tr>
<tr>
<td>Elasticity of substitution</td>
<td>$\theta$</td>
<td>0.49</td>
</tr>
<tr>
<td>Utility of home-ownership</td>
<td>$\zeta$</td>
<td>0.09</td>
</tr>
<tr>
<td>Consumption weights: at initial age</td>
<td>$\alpha$</td>
<td>0.55</td>
</tr>
<tr>
<td>Consumption weights: number of adults</td>
<td>$f_{adult}$</td>
<td>0.47</td>
</tr>
<tr>
<td>Consumption weights: number of children</td>
<td>$f_{child}$</td>
<td>0.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Demographics</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional probability of Survival</td>
<td>$p^S_a$</td>
<td></td>
</tr>
<tr>
<td>Mean number of adults</td>
<td>$N^a_{Adults}$</td>
<td>Figure 2</td>
</tr>
<tr>
<td>Mean number of children</td>
<td>$N^a_{Children}$</td>
<td>Figure 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Income process</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Deterministic permanent income growth rate</td>
<td>$\gamma_a$</td>
<td>Figure 2</td>
</tr>
<tr>
<td>Variance of stochastic permanent income</td>
<td>$\sigma_{\Phi,a}$</td>
<td>Figure 2</td>
</tr>
<tr>
<td>Variance of stochastic transitory income</td>
<td>$\sigma_{\Xi,a}$</td>
<td>Figure 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Borrowing</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest rate on savings</td>
<td>$r_s$</td>
<td>0.016</td>
</tr>
<tr>
<td>Interest rate on borrowing</td>
<td>$r_b$</td>
<td>0.054</td>
</tr>
<tr>
<td>Maximum loan to value ratio</td>
<td>$\mu_{LVR}$</td>
<td>0.90</td>
</tr>
<tr>
<td>Maximum debt to permanent income ratio</td>
<td>$\mu_{PermY}$</td>
<td>0.25</td>
</tr>
<tr>
<td>Maximum debt to present-value of income ratio</td>
<td>$\mu_{PV}$</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Housing</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.02</td>
</tr>
<tr>
<td>Transaction cost of purchase</td>
<td>$\kappa_p$</td>
<td>0.025</td>
</tr>
<tr>
<td>Transaction cost of selling</td>
<td>$\kappa_s$</td>
<td>0.025</td>
</tr>
<tr>
<td>Minimum quantity of housing</td>
<td>$h$</td>
<td>8.2</td>
</tr>
</tbody>
</table>

based on New Zealand Population data (2016, New Zealand Statistics).\(^\text{10}\) These are shown in the bottom-left panel of Figure 3.

The process on incomes is estimated based on Survey of Family, Income and Employment (SoFie) dataset from New Zealand Statistics. SoFIE was a panel (longitudinal) dataset collected annually from 2002 to 2010, after which it was discontinued. The 2002 wave covered 11,500 households. The Survey focused on income, wealth, debt, employment, and family relations; it did not collect data on expenditures. We now describe in turn how the SoFie data is used to estimate the deterministic, and both the permanent and transitory stochastic components of the income process given in equation (13).

Since age, year, and cohort effects are collinear we must impose assumptions to identify income growth (e.g., Deaton and Paxson (1994)). We estimate the deterministic growth rates of income $\{\gamma_a\}^A_{a_0}$

\(^{10}\)New Zealand Population Period Life Tables 2012-14. Total male population period life table, 201214. Probability that a male who reaches this age, Lives another year (px(1)), median (Column L, Table 5). Total female population period life table, 201214. Probability that a female who reaches this age, Lives another year (px(1)), median (Column L, Table 6).
as the growth rates of mean after-tax income over age in the data. We then fit a third-order polynomial to the implied levels of deterministic income\textsuperscript{11} to smooth these estimates, and normalize the smoothed level estimate for age \(a_0\) to one.\textsuperscript{12} The raw and smoothed estimates are shown in the top-left panel of Figure 3.

The permanent and transitory stochastic components of the income process are based on the regression:

\[
\log Y_{i,a} = f_i + \beta Z_{i,a} + y_{i,a}
\]

where \(f_i\) is a household fixed effect. \(Z_{i,a}\) is a vector of observable household-age-level (control) variables: an age dummy, education, number of children, number of adults, marital status, nationality, and geographic region. This gives estimates of the stochastic component of income \(y_{i,a}\) which we then decompose into permanent and transitory components in the following manner.

The stochastic component of income follows

\[
\Delta y_{i,a} = \phi_{i,a} + \Delta \xi_{i,a}
\]

As shown in Blundell, Pistaferri, and Preston (2008),\textsuperscript{13} age-specific variances of the permanent shocks are identified by

\[
\sigma_{\phi,a}^2 = \text{Cov}(\Delta y_{i,a}, \Delta y_{i,a-1} + \Delta y_{i,a} + \Delta y_{i,a+1})
\]

and age-specific variances of transitory shocks are identified by

\[
\sigma_{\xi,a}^2 = -\text{Cov}(\Delta y_{i,a}, \Delta y_{i,a+1})
\]

Due to different retirement decision around age 65 and to small (age-conditional) sample size at ages above this, the raw numbers for the variances become quite volatile. We therefore smooth them by fitting a cubic-spline polynomial for ages up to 62, and then set the variances for ages 63 and above to be constant at their age 62 level.\textsuperscript{14} Based on evidence from other countries this decision to set the

\textsuperscript{11}We tried fitting a third-order polynomial alternatively to both the growth rates and the implied levels, the performance was much better in levels.

\textsuperscript{12}Giving the estimated \(\{\Gamma_a\}_{a_0}^A\) the \(\{\gamma_a\}_{a_0}^A\) are then just the growth rates of these.

\textsuperscript{13}Blundell, Pistaferri, and Preston (2008) also describe an alternative estimation technique based on maximum-likelihood for estimating the same income process decomposition. We also implemented this alternative. The results differ in terms of the actual raw numbers, but the smoothed life-cycle profiles are not that different.

\textsuperscript{14}The cubic-spline polynomial is fit to the standard deviations, rather than the variances, and these smoothed standard variations are then squared to give the variances.
variances to be constant from age 63 up seems reasonable (retirement pensions is the dominant source of income for these households). The raw and smoothed estimates are shown in the top-right panel of Figure 3.

Both number of adults and number of children per household are set by smoothing the raw (age-conditional) means from SoFie by fitting fourth-order-spline polynomials.\(^\text{15}\) The raw and smoothed estimates are shown in the bottom-right panel of Figure 3.

\footnotesize
\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2}
\caption{Calibration of age-specific parameters}
\end{figure}

\begin{itemize}
\item Panel A: Deterministic Income
\item Panel B: Stochastic Income
\item Panel C: Conditional Survival Probabilities
\item Panel D: Family Composition
\end{itemize}

\subsection{4.3 Computation}

The life-cycle model is solved by value function iteration; using pure discretization and implemented in Matlab using the VFI Toolkit (Kirkby, 2017). Main results of the model (life-cycle profiles, regressions)

\footnotesize
\(^{15}\)Due to privacy concerns over being based on too few household-level observations, the raw numbers number of children for ages 88 and 90 were suppressed. For a few observations the quartic-spline smoothing gave negative numbers of children, these were overwritten with zero values.

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Figure 3: NZ Calibration of age-specific parameters

Panel A: Deterministic Income
Panel B: Stochastic Income
Panel C: Conditional Survival Probabilities
Panel D: Family Composition

are based on simulated panel data of 1000 households for 10 periods (10 years were chosen as this is the time between the first and last years of the empirical HES data we used).

The (partial equilibrium) transition path results are computed by first solving for the initial and final steady states. The value and policy functions along the path are then solved by backward induction from the final (steady-state) value function. Simulated panel data for 1000 households and 10 periods is then generated by drawing households at random from the initial (steady-state) distribution and simulating based on the policy functions.\textsuperscript{16}

4.4 Numerical Results

We begin by running the same regression analysis performed in the empirical analysis in Section 2 on simulated panel data from the model. The regressions are all done as pooled regressions (as the empirical

\textsuperscript{16}To avoid having to make assumptions on how the distribution of newborns evolves over the transition path any draws of households over 90 were simply redrawn.
data is cross-sectional and not panel). Table 4 is replication of Table 2.3.2 based on model simulated data. It is estimated from panel data based on the steady-state associated with \( p_H = 1 \).

<table>
<thead>
<tr>
<th>Dependent variable</th>
<th>i</th>
<th>ii</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing Wealth</td>
<td>0.07</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Leverage</td>
<td>-0.84</td>
<td>-0.58</td>
<td>-0.55</td>
</tr>
<tr>
<td>Leverage*Housing Wealth</td>
<td>-</td>
<td>-0.02</td>
<td>-0.06</td>
</tr>
<tr>
<td>Age<em>Leverage</em>Housing Wealth</td>
<td>-</td>
<td>-</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Note: Intercept not reported. Includes controls for age, age-squared, number of adults in HH, number of children in HH. Sample is restricted to Homeowners \((H > 0)\).

The regression results based on model-simulation data are broadly consistent with our empirical results in Table 2.3.2. In particular, the interaction term between housing leverage and housing wealth is consistently negative as in the empirical regressions. This is also true after we control for life cycle. In contrast to empirical findings, however, simulated data show that leverage appears to hold back consumption also on level. The empirical regression shows a positive estimate, albeit it is not statistically significant. It is due to the collinearity problem caused by the strong correlation between LTV and the leverage interaction with housing wealth in the data. Overall, regression results based on model-simulation data do confirm our empirical finding that housing leverage weakens instead of strengthening the housing wealth effect.

In the following, we consider variations in model’s parameters according to the insights gained from the two-period model in Section (3). We will simulate the full model with different parameters and study whether intuitions gained from the simple model also hold in the numerical solution. According to Section (3), both house price dynamics and risk aversion parameter should influence the relative MPCs between borrowers with high versus low leverages. Here, we vary the growth rate of house prices and the risk-aversion parameter, and study their implications for the regression coefficient for the interaction between leverage and housing wealth.

Panel A of Figure 4 summarizes the results of changing house prices. We consider three different cases of house price dynamics: (i) a constant price level of \( p_H = 1 \), (ii) price increases of 5% per year every year for the next ten years, (iii) price decreases of 5% per year every year for the next ten years. The increases of 5% per year were chosen as this is approximately the (compound) average growth rate of New...
Zealand house prices in the last decade\textsuperscript{17} We plot the estimated interaction coefficient for each scenario, represented by a dot. Consistent with the discussion above, the effect of the leverage ratio on the housing wealth effect turns out to be asymmetric. When house prices increase, the interaction coefficient becomes more negative than that when house prices go down. This helps reconcile the differences between our own empirical findings and those focusing on the Great Recession in the US. Furthermore, we also simulate data under three different risk-aversion parameter from 1.5 to 6. Panel B of Figure 4 summarizes the results of changing risk aversion on the interaction coefficient. In the full model, leverage weakens the housing wealth effect more as households become more risk averse.

A caveat from our theoretical analysis is that we treat interest rates and house prices as exogenous, which likely suppress some of important general equilibrium forces. We aim to make up this shortcoming in the future research.

5 Concluding Remarks

In this paper, we investigate the interaction between housing leverage and the housing wealth effect both empirically and theoretically. Empirically, we use New Zealand micro data to estimate the MPC out of exogenous changes in housing wealth and how it is affected by the household leverage ratio. Our empirical finding suggests a weakening role of leverage on MPC out of housing wealth. Furthermore, we

\textsuperscript{17}There was a 58% increase in NZ house prices from 2007-2017, the decade covered by our micro data. Calculated as total percent change from Mar 2007 to Mar 2017 in HPI.
use a theoretical model to show that optimal behavior of unconstrained households also matters for the interaction, which can be affected by many features, such as house price dynamics, the interest rate and household risk aversion.
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Matteo Iacoviello. House prices, borrowing constraints, and monetary policy in the business cycle. 


A  Household Economic Survey in New Zealand

The Household Economic Survey of Statistics New Zealand collects comprehensive data on household residents living in permanent dwellings. HES covers multiple aspects of household economics including highly disaggregate expenditures, income, and loans for every individual in the household. The survey also covers demographics, house ownership status, and house value. The data are stratified by different population benchmarks including age, sex, population per region, two adults and non-two adult households, and people of Maori ethnicity. This guarantees proper weighting of households and a high degree of comparability across time since the data are cross-sectional rather than longitudinal. Data are collected along one-year waves extending from July to June. In line with the literature, our study is primarily interested in non-housing expenditures (henceforth, ex-housing expenditure). This is to break the reverse causality between housing expenditures and house prices. The excluded housing expenditures are expenses on house maintenance, improvements, and mortgage repayment. HES disaggregate expenditure data are available triennially only. We, therefore, focus our analysis on the four waves with detailed expenditure data only. These waves are 2006-2007, 2009-2010, 2012-2013, and 2015-2016 and cover 7899 households. We also use the disaggregate expenditure data to break our ex-housing expenditures into durables, and non-durables. Appendix A lists the items of expenditures that fall into each of these categories. The address of each household in the survey is reported at different levels of aggregation. The population of New Zealand is broken down into 47062 meshblocks (MB), 2020 area units (AU), 65 territorial authorities (TA). In the empirical analysis, we control for regional fixed effects by using TA dummies and use the average house selling prices at the AU level.\textsuperscript{18} HES does not collect wealth-related data. For the particular purpose of this paper, however, HES reports the rateable value of the primary dwelling of the household and the year it was valued. The primary dwelling is the dwelling occupied by the respondents at the time of the interview. The rateable value of the dwelling is estimated by the territorial authority for levying rates. For the dwellings rated in years prior to survey date, we use REINZ data on house price inflation to ensure all house values are up to date. We inflate house prices on TA level. Households fall in one of three housing tenures: renters, owners with a mortgage, and owners without a mortgage. However, since house value is available for the primary property only, we exclude households with multiple properties from our analysis.\textsuperscript{19} To capture the actual income of

\textsuperscript{18}For more information about geographic boundaries, visit: http://www.stats.govt.nz/browse_for_stats/Maps_and_geography/Geographic_areas/digital-boundary-files.aspx

\textsuperscript{19}This is done through two stages. First, we exclude any household which owns a house and receives rental income on another property. Second, we exclude houses with debt to house value ratio of higher than 0.8. This is because it is most
Table 5: Descriptive statistics for homeowners over time

<table>
<thead>
<tr>
<th></th>
<th>Homeowner</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>all waves</td>
</tr>
<tr>
<td>Sample size</td>
<td>5099</td>
</tr>
<tr>
<td>Age</td>
<td>57.1 (18.1)</td>
</tr>
<tr>
<td>Person per household</td>
<td>2.4 (1.2)</td>
</tr>
<tr>
<td>Total expenditure</td>
<td>42,690 (32,125)</td>
</tr>
<tr>
<td>ex.housing (NZD)</td>
<td>85,671 (82,958)</td>
</tr>
<tr>
<td>Disposable income (NZD)</td>
<td>67,643 (62,305)</td>
</tr>
<tr>
<td>Housing wealth (NZD)</td>
<td>500,290 (457,085)</td>
</tr>
<tr>
<td>Total debt (NZD)</td>
<td>144,372 (141,904)</td>
</tr>
<tr>
<td>DTI</td>
<td>2.0 (1.7)</td>
</tr>
<tr>
<td>LTV</td>
<td>0.32 (0.24)</td>
</tr>
</tbody>
</table>

Notes: All nominal values are in New Zealand dollars. Homeowners include mortgagors and outright owners. Number of observations is rounded up or down randomly to a multiple of three in compliance with Statistics New Zealand rules.

Each household, we use the disposable annual income data reported by New Zealand Treasury, which is based on HES raw data and therefore match-able on house level.

Finally, inflation-adjusted house prices, disposable income, and debt data are used in constructing two different measures of household leverage. First, DTI is constructed by using total household debt and disposable income. Second, LTV is the ratio of total household debt over the primary house value at the time of survey. Both measures are based on outstanding debt rather than at the time of loan origination to capture the actual level of leverage when the household was interviewed.

### B Other Model Outputs

This appendix contains various model outputs that may be of interest including some policy functions and life-cycle profiles.

Figure 5 shows graph of leverage vs net worth.

likely that only households with multiple properties can have a loan to house value ratio higher than 0.8, especially after the Reserve Bank of New Zealand introduced the LTV restrictions in 2013. LTV is calculated at the time of survey not at mortgage origination date.
Table 6: Descriptive statistics by tenure type

<table>
<thead>
<tr>
<th></th>
<th>Home owner with mortgage</th>
<th>Outright home owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>1829</td>
<td>3270</td>
</tr>
<tr>
<td>Age</td>
<td>44.1 (14.7)</td>
<td>63 (16.1)</td>
</tr>
<tr>
<td>Person per household</td>
<td>2.9 (1.3)</td>
<td>2.0 (1.0)</td>
</tr>
<tr>
<td>Total expenditure ex.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>housing (NZD)</td>
<td>46,597 (26,643)</td>
<td>40,481 (34,868)</td>
</tr>
<tr>
<td>Total income (NZD)</td>
<td>100,720 (70,233)</td>
<td>76,392 (88,658)</td>
</tr>
<tr>
<td>Disposable income (NZD)</td>
<td>78,238 (50,313)</td>
<td>61,110 (67,852)</td>
</tr>
<tr>
<td>Housing wealth (NZD)</td>
<td>470,914 (321,906)</td>
<td>518,404 (522,543)</td>
</tr>
<tr>
<td>Total debt (NZD)</td>
<td>154,023 (143,027)</td>
<td>45,548 (78,572)</td>
</tr>
<tr>
<td>DTI</td>
<td>2.2 (1.7)</td>
<td>0.6 (1.0)</td>
</tr>
<tr>
<td>LTV</td>
<td>0.35 (0.23)</td>
<td>0.11 (0.18)</td>
</tr>
</tbody>
</table>

Notes: All nominal values are in New Zealand dollars. Number of observations is rounded up or down randomly to a multiple of three in compliance with Statistics New Zealand rules.

Figures 6 and 7 show some policy functions from the model (all for the same fixed level of income).

Figures 8, 9 and 10 shows some mean and median life-cycle profiles from the model.
Figure 5: Model: Leverage vs Net Worth
Figure 6: Model: Policy Functions
Figure 7: Model: Policy Functions
Figure 8: Model: Life-Cycle Profiles (1 of 2)

- **Net Worth**
  - Age vs. Net Worth
  - Mean and Median lines

- **Housing**
  - Age vs. Housing
  - Mean and Median lines

- **Debt**
  - Age vs. Debt
  - Mean and Median lines

- **Homeownership Rate**
  - Age vs. Homeownership Rate
  - Mean and Median lines
Figure 9: Model: Life-Cycle Profiles (2 of 2)

Figure 10: Model: Life-Cycle Profile of Leverage