Omitted Variable Bias and the Housing Wealth Effect

Narayan Bulusu Jefferson Duarte Carles Vergara-Alert*

August 2018

Abstract

This paper gauges the extent to which an omitted variable bias can help explain the observed housing wealth effect. We calibrate and simulate a model in which only a noisy proxy of the common driver of housing prices and non-housing consumption is observed. We find that controlling for the common driver with an imperfect, but very precise, proxy, we obtain estimates of elasticity of consumption to housing wealth that are similar to those estimated in the literature. Our analysis highlights the importance of further research exploring different instruments to estimate the extent that housing wealth effects are causal.

Keywords: Wealth effect; omitted variable bias; housing supply
JEL codes: E20; E21; D51; R21

*We thank David De Angelis, Kerry Back, Charles Calomiris, Alan Crane, Morris Davis, Michael Eriksen, Scott Hendry, Matteo Iacoviello, Leonid Kogan, Vincent Labhard, William Lastrapes, Veronika Pool, David Williams, Callan Windsor, Shaofeng Xu as well as participants of the 2017 FMA European Conference, the 2017 China International Conference in Finance, the 2018 International American Real Estate and Urban Economics Association Conference, and seminars at the Bank of Canada Fellowship Exchange, PUC-Rio and University of Washington for their helpful comments. This paper was previously titled "Can the Common-Factor Hypothesis Explain the Observed Housing Wealth Effect?" Bulusu is with the Bank of Canada, Duarte with the Jesse H. Jones Graduate School of Business, Rice University and Vergara-Alert is with IESE Business School, University of Navarra. E-mail addresses: nbulusu@bank-banque-canada.ca (Bulusu), jefferson.duarte@rice.edu (Duarte), CVergara@iese.edu (Vergara-Alert). Carles Vergara-Alert acknowledges the financial support of the Public-Private Sector Research Center at IESE, the Ministry of Economy of Spain (ref. ECO2015-63711-P) and the Government of Catalonia (ref: 2014-SGR-1496). The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

Estimates of the elasticity of consumption to housing wealth are usually large and positive. Indeed, using data on non-housing consumption growth and housing price appreciation at the U.S. state level, Case, Quigley, and Shiller (2005, 2013) estimate that the elasticity of consumption to real estate wealth is between 4.4% and 18%, after controlling for growth in income. These estimates are significantly larger than those of stock market wealth. Such a strong housing wealth effect has important policy implications if the relation between housing wealth and non-housing consumption is causal.

The literature presents strong evidence that credit-constrained homeowners use housing assets as collateral to finance consumption, and hence housing price appreciation causes non-housing consumption growth.[1] Even though this collateral channel has been established in the literature, it is unclear the extent to which collateral effects can explain the elasticity of aggregate consumption to housing wealth estimated in the literature. Indeed, using a model that takes into account the presence of collateral effects, Iacoviello and Neri (2010) conclude that about 2.5% out of a 13.5% elasticity of consumption to housing wealth is due to the collateral effect.

In this paper, we gauge the extent to which an omitted variable bias can help explain the elasticity of consumption to housing wealth estimated with U.S. state-level data that is not due to the housing collateral channel.[2] To formalize the omitted variable bias, assume that the collateral channel is absent, and that a single unobservable variable Δk (e.g., permanent income growth) drives consumption growth. Because housing supply is inelastic, Δk also drives growth in housing wealth. That is, consumption growth is given by $\Delta c = \gamma_c \Delta k$ and housing appreciation is $\Delta w^H = \gamma_{w^H} \Delta k$ where γ_c and γ_{w^H} are positive constants. Assume that we only observe a noisy proxy of Δk, such as growth in income.[3] Moreover, in reality, we do

[1]For example, Leth-Petersen (2010), Abdallah and Lastrapes (2012), Mian, Rao, and Sufi (2013), Agarwal and Qian (2017), Aladangady (2017), Fan and Yavas (2018) and DeFusco (2018) show the importance of this mechanism in micro-data, while Iacoviello (2005), Chen, Michaux, and Roussanov (2013), Justiniano, Primiceri, and Tambalotti (2015) and Guerrieri and Iacoviello (2017) provide evidence for the collateral channel using aggregate data.

[2]Attanasio, Blow, Hamilton, and Leicester (2009) were perhaps the first to point out that shocks to permanent income drive both demand for housing and non-housing consumption. Since housing supply is somewhat inelastic, these shocks also affect housing prices. As a result, when we omit permanent income shocks from the regression used to estimate the housing wealth effect, the estimated elasticity of consumption to housing wealth is positive.

[3]Income growth is a noisy proxy for shocks to permanent income since the former includes transitory shocks to earnings unrelated to changes in the latter.

not observe Δc or Δw^H either; instead we observe noisy proxies of consumption and housing wealth growth.[4] Let the variables observed with noise be $\Delta\widetilde{c}^H = \Delta c + \varepsilon^c$, $\Delta\widetilde{w}^H = \Delta w^H + \varepsilon^H$, and $\Delta\widetilde{y} = \Delta k + \varepsilon^k$, where ε^c, ε^H, and ε^k are measurement errors with variances $\sigma^2_{\widetilde{c}}$, $\sigma^2_{\widetilde{H}}$, and $\sigma^2_{\widetilde{k}}$ respectively, and are uncorrelated with Δk, amongst themselves, and over time. We show in Section 2 that the omitted variable bias implies that we find a positive β_{w^H} in the regression $\Delta\widetilde{c} = \alpha + \beta_{w^H}\Delta\widetilde{w}^H + \beta_y\Delta\widetilde{y} + \epsilon$ because $\Delta\widetilde{w}^H$ picks up some of the variation in the omitted variable Δk – even when $\Delta\widetilde{y}$ is a very precise, but imperfect, proxy for Δk. In this paper, we gauge the size of the noise-to-signal ratios of the observable housing wealth and income growth necessary to obtain estimates of the elasticity of consumption to housing wealth (β_{w^H}) similar to those that we estimate with U.S. state-level data.

To do so, we use a general equilibrium model in which one underlying variable drives both consumption and housing prices. The model is an application of the Kogan (2001, 2004) two-sector model to housing. The representative agent in the model has utility for housing services and consumption goods. There are two types of capital in this model – housing and non-housing capital. Non-housing capital is used to fund consumption and invest in housing, while housing capital is needed to produce housing services.

The model endogenously creates a housing supply curve that resembles the classic kinked supply commonly described in real estate text books (e.g., Geltner, Miller, Clayton, and Eichholtz (2013)). Indeed, housing supply in the model is inelastic up to the point that housing prices equal housing replacement costs, and is perfectly elastic when housing prices are equal to housing replacement costs. This kinked supply curve results from the model's assumption that investment in housing is irreversible in the aggregate.[5] Therefore, situations in which there is 'too much' housing can exist in this model. In these states of the world, new housing is not built and housing prices are lower than housing replacement costs. As a consequence, shocks to non-housing capital drive shocks to both consumption and house prices. Most importantly, the fact that the model endogenously generates an inelastic supply of housing based on a simple and realistic friction implies that our results are not an artifact

[4]The literature recognizes that the data used in the estimation of housing wealth effects are plagued with measurement errors (see, e.g., Muellbauer (2007) and Calomiris, Longhofer, and Miles (2012)).

[5]The irreversibility of housing investment, a cornerstone of this model, is the natural consequence of the fact that, in the aggregate, we cannot convert housing into non-housing consumption.

of ad-hoc assumptions related to the elasticity of housing supply.[6]

Armed with this model, we follow a three-step procedure to appraise the extent to which the omitted variable bias can generate the large elasticity of consumer spending to housing wealth estimated in the literature. First, we calibrate the model to match the observed moments of consumption and house-price growth in each U.S. state and the District of Columbia. Second, we simulate the model to generate, for each state, time series of consumption growth, housing price appreciation, and changes in non-housing capital. In our simulations, we assume that these variables are observed with measurement errors. Third, we estimate panel regressions analogous to those used in the housing wealth effect literature with simulated data to gauge the magnitude of noise-to-signal ratios on housing wealth and on the proxy of the omitted variable necessary to achieve the same level of elasticity of consumption to housing wealth that we observe in U.S. state-level data.

The magnitude of the housing wealth effect that we find in our model-simulated panels is similar to that we estimate using U.S. state-level data even with small noise-to-signal ratios.[7] For instance, when the variance of the measurement errors is 5% of the variance of the non-housing capital and housing price growth (i.e., a noise-to-signal ratio of 5%), the elasticity of consumption to housing wealth is about 15%. This is close to the 13% level of elasticity of consumption to housing wealth that we estimate using historical state-level data, and is within the range of 2% to 19% estimated in the literature using U.S. and non-U.S. data.[8] To wit, this result indicates that the omitted variable bias can lead to an estimated elasticity of consumption to housing wealth equal to 15% even when we control for the omitted variable with a proxy that explains about 95% of the variation in the omitted variable. For all (non-zero) noise-to-signal ratios that we analyze, the minimum elasticity to housing wealth that

[6] In contrast to the geographical and regulatory restrictions that generate inelastic housing supply (see, e.g., Saiz (2010) and Gyourko, Saiz, and Summers (2008)) which usually are not relevant in large geographical units such as states and countries, the inelastic housing supply in our simulated model depends on the inability to transform housing in non-housing consumption in aggregate. The latter friction applies to geographical units with large amount of land available for construction.

[7] The size of the measurement errors needed to generate the housing wealth effect in historical data is within the range of errors in these variables estimated in the literature. We briefly review the literature on the errors in variables used in empirical studies of the housing wealth effect in Section 2.

[8] See, for instance, Benjamin, Chinloy, and Jud (2004), Bostic, Gabriel, and Painter (2009), Calomiris, Longhofer, and Miles (2012), Case, Quigley, and Shiller (2005, 2013), Carroll, Otsuka, and Slacalek (2011), Dvornak and Kohler (2007), Labhard, Sterne, and Young (2005), and Ludwig and Sløk (2002). See Mishkin (2007) and Paiella (2009) for reviews of this literature.

we find is about 8%. This minimum occurs when the noise-to-signal ratios of non-housing capital growth and housing price growth are 5% and 30%, respectively. That is, even when housing price growth is six times noisier (30% ÷ 5%) than the common driver of consumption and housing wealth growth, the simulated elasticity of consumption to housing wealth is well within the range of elasticities estimated in the literature.

The simulated model is ideal for analyzing the extent to which the omitted variable bias explains the housing wealth effect for two reasons. First, any housing wealth effect that we find in our simulations cannot be confounded by effects unrelated to the omitted variable bias. Our simulated model is fairly simple and does not consider many effects that might affect housing prices and consumption. For instance, the simulated model does not include labor income, which has long been recognized as an important determinant of consumption (Iacoviello (2012)).[9] While the simplicity of our model may not allow it to fully capture the dynamics of housing prices and non-housing consumption, it helps us to attribute the housing wealth effect in our simulations entirely to the omitted variable bias. Second, the simulated model generates housing wealth effects from the generally-accepted premises that housing cannot be converted into non-housing consumption in the aggregate and that econometricians can only observe noisy proxies of the variables affecting consumption.

Part of the literature uses household-level data to estimate the elasticity of consumption to housing wealth.[10] Even though we focus on the estimation of housing wealth effects using aggregate data at the U.S. state level, our results are also applicable to estimation of the elasticity of consumption to housing wealth with household-level data. Household level data likely have smaller measurement errors than state level aggregate data; however, this does not eliminate the omitted variable bias. The intuition for this result is that the bias of an omitted variable on the elasticity of consumption to housing wealth depends on the quality of the proxy for the omitted variable. In other words, while income growth may indeed be

[9] In the model we calibrate, the common driver of consumption and housing wealth is the growth of non-housing capital. We, however, do not make any statements about the economic nature of this common driver in the actual data. For instance, in reality, income growth is a proxy for this common factor, which can be, e.g., shocks to permanent income (Attanasio, Blow, Hamilton, and Leicester (2009) and Calomiris, Longhofer, and Miles (2009)), or confidence in the economy (Case, Quigley, and Shiller (2005, 2013)). Our econometric results do not rely on the economic nature of the common factor.

[10] For example, Campbell and Cocco (2007) and Gan (2010) use household-level data to analyze the housing wealth effect due to heterogeneity in demographics and ownership of multiple homes.

better measured at the household level, it may still not be a perfect proxy for the omitted variable driving growth in consumption and in housing wealth. In fact, we show in Section 2 that household-level data could even exacerbate the effect of an omitted variable bias on the estimation of the elasticity of consumption to housing wealth.

Our methodology uses ingredients from both general equilibrium models and the reduced form empirical literature estimating the housing wealth effect. For example, Iacoviello and Neri (2010) develop a DSGE model with housing and non-housing sectors to examine the extent to which spillover effects related to the housing collateral hypothesis drive the elasticity of consumption to housing wealth. Iacoviello and Neri (2010) calibrate their model using data from 1965 to 2006 and conclude with simulations that only about 2.5% out of a 13.5% elasticity of consumption to housing wealth is due to the housing collateral effect. Iacoviello and Neri (2010) do not include in their analysis a noisy proxy for the factor driving both consumption growth and housing wealth, as we do. By doing so, we mimic the panel regressions used in the empirical literature (e.g. Case, Quigley, and Shiller (2005)), which always include variables such as income growth that proxy for the common driver of consumption growth and housing prices.

Instrumental variables (IVs) can be used to deal with omitted variables in the estimation of the elasticity of consumption to housing wealth. For example, Calomiris, Longhofer, and Miles (2009, 2012) use lagged variables as instruments. Under the premise that the permanent income hypothesis (PIH) holds, these instrumental variables address the fact that change in permanent income is an omitted variable.[11] This IV approach does not rule out the effect of omitted variable biases in the estimation of housing wealth effects for at least two reasons.[12] First, the choice of lagged variables as instruments addresses the fact that permanent income is an omitted variable if the PIH holds. However, there is plenty of empirical evidence that the PIH does not hold (e.g., Campbell and Deaton (1989) and Campbell and Mankiw (1990)). Second, the omitted variable that drives demand for housing

[11] The PIH states that consumption at a point in time is a function not only of current income but also of expected future income (permanent income). As a result, under the PIH, changes in consumption behave as a random walk because only unexpected changes in permanent income drive changes in consumption (Hall (1988)). Moreover, under the PIH, changes in consumption are uncorrelated with lagged changes in housing wealth.

[12] We show that our results are robust to using lagged variables as instruments in Appendix D.

and non-housing consumption does not need to be permanent income. For instance, Case, Quigley, and Shiller (2005, 2013) point out that general confidence in the economy can be the omitted variable driving non-housing consumption and housing wealth. Another example of the IV approach is Mian, Rao, and Sufi (2013). They use variation of elasticity of supply across MSAs as a means to identify exogenous shocks to housing prices during the 2002 to 2006 period. Guren, McKayy, Nakamura, and Steinsson (2018) explore differences in city-level exposure to their region real estate prices to instrument for housing price shocks. They find an elasticity of consumption to housing wealth of about 7% between 1990 and 2015.

Naturally, the challenge of using IV to estimate housing wealth effects is to find instruments that are related to housing prices and unrelated to omitted variables driving consumption growth. While a comprehensive analysis of IV-based estimates of the housing wealth effect is outside the scope of this paper, our central result – that very precise, but imperfect proxies of the omitted variable could generate large housing wealth effects – highlights the importance of research exploring different instruments to estimate the causal relation between housing prices and consumption growth.

The rest of this paper is organized as follows. Section 1 describes our data. Section 2 estimates the housing wealth effect at the state level. Section 3 explains the simulated model. Section 4 shows the estimation of the housing wealth effect in the simulated data, and Section 5 concludes.

1 Data

Table 1 describes the variables used in our empirical work. Our empirical analysis relies on three data series: annual real growth in housing wealth ($\Delta\widetilde{w}^H$), annual growth in real aggregate income ($\Delta\widetilde{y}$), and annual real log-consumption growth ($\Delta\widetilde{c}$).[13] We build the $\Delta\widetilde{w}^H$ series based on the FHFA-index at the state level. Since, FHFA-index data start in 1975, our state-level growth dataset starts in 1976 and ends in 2012. We build the $\Delta\widetilde{y}$ series from Bureau of Economic Analysis (BEA) total nominal income data. We use state-level consumption growth estimates from Zhou (2010) and Zhou and Carroll (2012). The consumption growth

[13]We use the notation $\widetilde{x}$ to represent a variable that is observable by the econometrician and is equal to x plus some measurement error.

data start in 1971 for all but six states (Alaska, Delaware, Montana, Nevada, New Hampshire, and Oregon), whose consumption growth data are only available from 1998 onward.

Our focus is on the housing wealth effect and not on the financial wealth effect, therefore we only include tradable wealth as a control to show that our estimated housing wealth effects are robust to controlling for annual real growth in non-housing tradable wealth ($\Delta\widetilde{w}^{TR}$). We build the $\Delta\widetilde{w}^{TR}_{i,t}$ data series from total nominal tradable assets in the U.S. ($\widetilde{w}^{TR}_{US,t}$) and the growth of cumulative disposable income (CDI) in each state i between 1960 and year t. Specifically, the total real tradable wealth ($\widetilde{w}^{TR}_{i,t}$) for state i at year t is $\widetilde{w}^{TR}_{US,t} \times CDI_{i,t}/\sum_{i=1}^{50} CDI_{i,t}$ deflated by CPI. CDI is calculated from 1960 because this is the first year for which we have disposable income data for all states. We use a different procedure from that in Case, Quigley, and Shiller (2005) to calculate $\widetilde{w}^{TR}_{i,t}$. Case, Quigley, and Shiller (2005) use mutual fund holdings by state from the Investment Company Institute (ICI) to allocate national tradable wealth data to states. Their working assumption is that the total financial assets in a state as a proportion of nationwide financial assets is equal to the mutual fund assets in the state divided by total mutual fund assets in the U.S. They recognize that this is clearly a strong assumption. Our procedure, on the other hand, is based on the working assumption that cumulative disposable income from 1960 to year t is a proxy for accumulated savings in state i. This is also a strong assumption, but if our procedure is materially different from that of Case, Quigley, and Shiller (2005), then we would expect to find different wealth effects than they did. As we show in Section 2, our estimated wealth effects are similar to those in the literature.

Table 2 displays summary statistics, and Table 3 shows the correlations among the consumption growth of different states. We use these summary statistics and correlations to calibrate the model at the state level in Section 4. Consumption growth in different states tends to be positively correlated, with the exception of Hawaii, where it is negatively correlated with that of most of the other states. These correlations are somewhat noisy because they are based on a sample of consumption growth that starts in 1998 due to the six states that only had data available beginning that year. In fact, if we estimate the correlation of consumption growth in Hawaii with that in other states using the entire sample, we find that it is not as negatively correlated with that of the rest of the U.S. as Table 3 suggests.

2 Housing wealth effect

Following prior literature on the housing wealth effect (see, e.g., Case, Quigley, and Shiller (2005)), we test for the presence and magnitude of the housing wealth effect in panel regressions of the type

$$\Delta\widetilde{c}_{i,t} = \alpha_i + \beta_{w^H}\Delta\widetilde{w}^H_{i,t} + \beta_y\Delta\widetilde{y}_{i,t} + \epsilon_{i,t}, \tag{1}$$

where i is the state index and t is the time at which the variables are being measured. $\Delta\widetilde{c}_{i,t}$, $\Delta\widetilde{w}^H_{i,t}$, and $\Delta\widetilde{y}_{it}$ are, respectively, the log growth in aggregate consumption, housing wealth, and income in geographic area i from $t-1$ to t. All regressions include state fixed effects. Some of our regressions control for growth in tradable wealth.

Table 4 reports the results of the regression in Equation 1. The results in Specification 4 show an economically and statistically significant wealth effect.[14] The estimated elasticity of consumption with respect to housing wealth is 13%. Of the two estimated elasticities of consumption, the elasticity of consumption with respect to income is the largest at 64%. Indeed, the R^2 in Specification 2 is approximately 15%. When we add housing wealth, the R^2 increases to 17%, indicating that housing wealth explains only a small part of the variation in consumption growth after accounting for income growth. Overall, our results are consistent with those in the literature that use state-level data. The housing wealth and the income elasticities in Specification 4 are in line with those in Case, Quigley, and Shiller (2013).

The estimation of the elasticity of consumption to housing wealth in Equation 1 is prone to omitted variable bias because of two reasons. First, housing supply is somewhat inelastic and therefore an omitted variable that affects the demand for housing and non-housing consumption also affects housing prices. Second, income growth is the variable in this regression that possibly proxies for the omitted variable that drives housing prices and consumption growth (e.g., shocks to permanent income). Income growth, however, is an imperfect proxy for permanent income shocks because it is also affected by transitory income shocks and has substantial measurement errors. In fact, all variables in this regression have sizable

[14] Results with T-statistics based on standard errors clustered by geographical region are qualitatively similar to those in Table 4 and are available upon request.

measurement errors.[15]

To see the role of the omitted variable bias in generating a positive elasticity of consumption to housing wealth in the OLS setting typically employed in the literature, consider the case in which a single unobservable variable Δk with variance σ_k^2 drives both consumption growth Δc and housing wealth growth Δw^H. More formally, let $\Delta c = \gamma_c \Delta k$ and $\Delta w^H = \gamma_{w^H} \Delta k$, where Δk could be, e.g., the growth in permanent income. Now, let consumption and housing wealth be observed with errors: $\Delta \widetilde{c} = \Delta c + \epsilon^c$, $\Delta \widetilde{w}^H = \Delta w^H + \epsilon^H$. Further assume that we observe a noisy proxy of Δk, such as income growth: $\Delta \widetilde{y} = \Delta k + \epsilon^k$.[16] ϵ^c, ϵ^H and ϵ^k are mean-zero measurement errors with variances of $\sigma^2_{\widetilde{c}}, \sigma^2_{\widetilde{H}}$ and $\sigma^2_{\widetilde{k}}$, respectively. Also assume, for simplicity, that ϵ^c, ϵ^H and ϵ^k are uncorrelated with each other, over time, and with $\Delta c, \Delta w^H$ and Δk.

In this setting, the coefficient β_{w^H} in the regression $\Delta \widetilde{c} = \alpha + \beta_{w^H} \Delta \widetilde{w}^H + \beta_y \Delta \widetilde{y} + \eta$ is positive as long as $\sigma^2_{\widetilde{k}}$ is not zero. To see this, note that the OLS estimate of β_{w^H} converges to

$$\frac{\gamma_c}{\gamma_{w^H}} \times \frac{\sigma^2_{\widetilde{k}}/\sigma^2_k}{\sigma^2_{\widetilde{k}}/\sigma^2_k + \sigma^2_{\widetilde{k}}/\sigma^2_k \times \sigma^2_{\widetilde{H}}/\gamma^2_{w^H}\sigma^2_k + \sigma^2_{\widetilde{H}}/\gamma^2_{w^H}\sigma^2_k}, \tag{2}$$

where σ_k^2 is the variance of the omitted variable Δk. Thus, $\beta_{w^H} \neq 0$ when $\sigma^2_{\widetilde{k}} \neq 0$. Intuitively, when the proxy for the omitted variable is imperfect, the coefficient of housing wealth growth captures part of the growth in consumption that is masked due to the errors in observing the true driver of consumption and housing wealth, Δk. Further, the strength of the relationship between $\Delta \widetilde{w}^H$ and $\Delta \widetilde{c}$ depends on the precision of the observed variables. To see this, note from Equation 2 that the magnitude of β_{w^H} depends on the noise-to-signal ratios of the observed variables, $\sigma^2_{\widetilde{H}}/\gamma^2_{w^H}\sigma^2_k$ and $\sigma^2_{\widetilde{k}}/\sigma^2_k$. Accordingly, in the analysis that follows, we simulate data with different noise-to-signal ratios to test the errors in variables that would be needed to produce the estimates of the housing wealth effect observed in the data.

[15]Indeed, there is a consensus in the literature about the existence of measurement errors in housing prices. The literature documents that the overestimation of reported house values is between -2% and 16%. See Kish and Lansing (1954), Kain and Quigley (1972), Robins and West (1977), Follain and Malpezzi (1981), Ihlanfeldt and Martinez-Vazquez (1986), Goodman and Ittner (1992), Kiel and Zabel (1999), Agarwal (2007), and Benítez-Silva, Eren, Heiland, and Jiménez-Martín (2015). The magnitude of the measurement error in income is also sizable. The income data normally used in housing wealth effect studies are from the BEA. The BEA methodology for compiling income data involves surveys, state-level records (tax filings, etc.), and further needs imputations of residential status. Moore and Welniak (2000) provide a literature review of the quality of survey measures of income and report measurement errors that range from 2% to above 50%.

[16]ϵ^k is the short-term driver of income growth that is unrelated to the growth in permanent income.

Equation 2 has the additional implication that even when using household level data, the coefficient on housing wealth in Regression 1 would still be positive to the extent that a perfect proxy of the permanent income at the household level is not available. In fact, the use of household level data could even exacerbate the effect of an omitted variable bias on the magnitude of the estimated β_{w^H}. To see this, assume for example that household level data allows us to observe housing prices without any measurement errors, i.e., $\sigma^2_{\widetilde{H}}/\gamma^2_{w^H}\sigma^2_k = 0$, while income growth is not perfectly correlated with the omitted variable that drives growth in both consumption and housing prices, $\sigma^2_{\widetilde{k}}/\sigma^2_k > 0$. Therefore in this case, the OLS estimate of β_{w^H} in Equation 2 would converge to γ_c/γ_{w^H}, which is the upper bound for the estimate of the housing wealth effect. The intuition for this result is that the bias of an omitted variable on the elasticity of consumption to housing wealth depends on the relation between the measurement errors in housing wealth and the quality of the proxy for the omitted variable. Therefore, our results also provide a note of caution to studies using micro-data (which typically find large housing wealth effects).

3 A model with inelastic housing supply

In the remainder of the paper we gauge the standard deviation of the errors $\sigma_{\widetilde{c}}$, $\sigma_{\widetilde{H}}$, and $\sigma_{\widetilde{k}}$ necessary to match the coefficient β_{w^H} that we estimate with U.S. state-level data. To do so, we rely on a model that endogenously specifies the relation between the omitted variable Δk, housing price appreciation, and consumption growth. The model is a standard two-sector economy model with only one friction – housing cannot be converted to non-housing consumption. Specifically, we use the general equilibrium model of a two-sector production economy developed in Kogan (2001, 2004), where we interpret the durable goods sector with irreversible capital stock as housing. We do not claim that this model explains consumption growth well, as it does not include factors such as labor income, which is an important driver of consumption decisions. However, this model is well-suited to examining the effect of measurement errors because it allows consumption and housing prices to be driven by a common factor that we assume is measured with errors in our simulations in Section 4. We now briefly describe this model.[17]

[17] See Kogan (2001, 2004) for a detailed description of the model.

In the Kogan (2001) model, there are two productive sectors, each with the specialized capital input required to produce the two types of consumption goods or services in the economy. Capital in sector H (the housing sector) can only produce housing services. Capital in sector K (the non-housing sector) can be either used to produce the consumption good, C, or converted into housing stock, H. Investment in the housing sector is irreversible; that is, houses cannot be liquidated into consumption goods or transformed into non-housing capital.

The stock of non-housing capital (K_t) follows the equation of motion

$$dK_t = (\alpha K_t - C_t)dt + \sigma K_t dW_t - dI_t, \tag{3}$$

where α and σ are, respectively, the mean and the volatility of shocks to growth in non-housing capital, and dW is an increment of a standard Brownian motion. Changes in the housing stock are given by

$$dH_t = -\delta H_t dt + dI_t, \tag{4}$$

where δ is the rate of depreciation. The choice variables are consumption (C_t), and investment in the housing sector in each period (dI_t), both of which are non-negative. We follow Kogan (2001) and set the housing replacement cost to unity. This normalization implies that one unit of non-housing capital builds one unit of housing.

Households maximize their expected lifetime utility:

$$\max_{\{C_t, I_t\}_{0 \le t < \infty}} E_0 \left[\int_0^\infty e^{-\rho t} U(C_t, XH_t) dt \right], \tag{5}$$

where ρ is the parameter that specifies household impatience. Households have separable utility over consumption good, C_t, and housing services, XH_t, given by

$$U(C_t, XH_t) = \frac{1}{1-\gamma} (C_t)^{1-\gamma} + \frac{b}{1-\gamma} (XH_t)^{1-\gamma}, \gamma > 0, \gamma \neq 1, \tag{6}$$

where γ is the curvature of the utility function, b can be interpreted as the parameter that captures the size of the housing sector as a fraction of the whole economy and X represents the productivity of the housing sector.

Kogan (2001) shows that an equilibrium exists in which the processes for K_t, H_t, C_t, and I_t are equivalent to the solution of a central planner problem with choice variables C_t and

I_t that solves Equation 5 subject to Equations 3 and 4. Appendix A provides details of this equilibrium.

Because housing investment is irreversible, the central planner wants to avoid an excess of housing. Therefore, in this model, no increase in housing supply inheres unless the level of housing capital relative to non-housing capital is below a certain threshold. In fact, the central planner's choice of the control variables depends only on the state variable $\omega_t = \ln(\Omega_t) = \ln(H_t/K_t)$, and the optimum housing investment policy is such that investment in housing only happens if ω is less than or equal to an endogenously determined threshold, ω^*. Formally, the agent chooses $I_t = 0$ at t when $\omega_t > \omega^*$ and $I_t > 0$ otherwise. When $\omega_t = \omega^*$, the agent invests just enough to revert to ω^*. That is, ω_t can never be below ω^*; thus, investment occurs when $\omega_t = \omega^*$ and the inelasticity of the housing supply is driven only by the irreversibility of housing investment.[18]

The Tobin's q of housing (i.e., the ratio of the market value of housing to its replacement value) is equal to the market value of housing, because the replacement value of housing is assumed to be one. Tobin's q of housing is smaller than or equal to one, since the market value of housing cannot exceed its replacement value. As soon as the two are equal, housing supply increases and applies downward pressure on the market value of housing.

In the absence of a known analytical characterization of the model equilibrium, we solve the model numerically to better explain its inner workings. Table 5 reports the parameters used in the numerical solution of the model: b, δ, ρ, γ, and X. Recall that b parameterizes the size of the housing sector as a fraction of the total economy. To choose this parameter, we begin by partitioning total wealth into housing wealth, tradable asset wealth, and human capital. In the U.S., the ratio of human capital to total wealth is estimated to be between 0.75 and 0.92 (see Lustig, Van Nieuwerburgh, and Verdelhan (2013), Palacios (2015), Di Giovanni and Matsumoto (2011) and Jorgenson and Fraumeni (1989)). Assuming that the ratio of housing to tradable asset wealth is between 0.67 and 1.50, we calculate that housing wealth is between 0.03 and 0.15 of the total wealth in the U.S. We set $b = 0.1$, close to the midpoint

[18] Kogan (2004) also extends this model in which investment is bounded below an exogenously specified bound. In this extension, housing supply is not perfectly elastic when housing prices are equal to housing replacement costs. This upper bound on housing supply can potentially be important to match housing price dynamics in areas with restricted land availability such as geographically constrained cities. We do not use the extended model in our simulations because we focus on state-level data.

of this range. The value of the time-discounting parameter ρ is typically set to between 0.01 and 0.05 (see Flavin and Nakagawa (2008), Piazzesi, Schneider, and Tuzel (2007), Cocco (2005), and Lustig and Van Nieuwerburgh (2005)). We set $\rho = 0.02$. The parameter δ is the rate of depreciation of housing stock. We assume a value of $\delta = 1.3\%$, which falls within the range of estimates produced in the literature. Harding, Rosenthal, and Sirmans (2007), Knight and Sirmans (1996), Shilling, Sirmans, and Dombrow (1991), Leigh (1980) and Malpezzi, Ozanne, and Thibodeau (1987), using data at various levels of aggregation and for different time periods, estimate that the rate of housing stock depreciation is between 0.43% and 2.18%. For the curvature of the utility function parameter γ, we use a value of 1.2 and set the productivity of the housing sector parameter X equal to 1/30.

It is natural to assume that the parameters in Table 5 are constant across different U.S. states. These parameters are related to the utility function of the representatives agents in the model, and we should not expect major variation in these parameters across different states. On the other hand, the rate of growth (α) and volatility (σ) of non-housing capital as well as the initial value of the state variable (ω_0) may have some variation across different states – for example, because the economy in different states is based on different industries. We describe the choice of the parameters that vary across states in Section 4.

Figure 1, Panel A plots the price per unit of housing and the ratio of consumption to non-housing capital (C/K) as a function of ω, the logarithm of the ratio of housing to non-housing capital.[19] The fact that the agent is always able to transfer an unlimited amount from non-housing capital to housing stock ensures that ω never falls below ω^*, which means that the investment region is the point $\omega = \omega^*$ and the non-investment region is the entire region to the right of ω^* in Panel A. Note that the ratio of consumption to non-housing capital slightly decreases as ω gets closer to ω^*: essentially, households consume less non-housing capital, anticipating the possibility of investment in housing. Moreover, since the housing sector is perfectly competitive, the ability to invest without limits ensures that the market value of housing stock never rises above its replacement value, and Tobin's q reaches its maximum

[19]For the example solution of the model in Figure 1, we set α, σ and ω_0 equal to $4.05\%, 6.18\%$ and 1.58%, respectively. As we show in Section 4, these parameter values allow us to match the model mean consumption growth, volatility, and mean housing wealth growth to those observed in Minnesota from 1987 to 2010. We use Minnesota as an example because its mean consumption and housing wealth growth are close to the mean across all 50 states and the District of Columbia in our sample.

value of one when the agent invests in housing. Within the no-investment region, as ω increases, housing prices drop. There is 'too much' housing in the non-investment regions and housing prices adjust, since housing capital cannot be transformed into non-housing consumption.

Indeed, the non-linearity in C/K and Tobin's q with respect to ω is due to the irreversibility of housing investment. If housing capital were fully reversible to non-housing capital, then housing price would be equal to the replacement cost (which is constant in this model). Further, consumption would be a constant fraction of non-housing wealth. Thus, if housing investment were perfectly reversible, consumption would be a linear function of non-housing capital, and would be unrelated to housing price, which would be constant.

Figure 1, Panel B plots the log of housing price (p) and the log of consumption (c) as functions of the log of non-housing capital (k) under the assumption of a fixed housing capital (H).[20] Panel B shows that c is closely approximated by a linear function of k in this model, given that the variation in C/K is small. Moreover, except when investment in housing is proximate, p is also close to a linear function of k. Housing wealth increases with non-housing capital due to the irreversibility of housing capital. As discussed previously, if investment in housing were completely reversible, its price would be a constant in this model and would not vary with consumption.

To gauge the size of the measurement errors necessary to explain the housing wealth effect observed in the state-level data, we calibrate this model and estimate a regression analogous to Regression 1 with simulated data.

4 Housing wealth effect and the size of measurement errors

Table 5 reports the values we use in the simulation exercise for the parameters common to all states. We calibrate the correlation of non-housing capital shocks (dW) to match the correlation of consumption growth across states shown in Table 3. The parameters α_i, σ_i, and $\omega_{0,i}$ vary across states. We choose α_i and σ_i to match the mean and volatility of consumption growth in state i in our sample (see Table 2). We follow two different procedures to calibrate

[20] Appendix A gives details of the procedure used to plot this figure.

$\omega_{0,i}$.[21]

In our first calibration procedure, we choose $\omega_{0,i}$ for each state i to match the mean growth of housing stock in Table 2. Panel A of Table 6 displays the average of the mean and volatility of log consumption growth as well as the mean and volatility of log housing price growth across 500 simulations of the model. Panel A of Table 6 also displays the parameters α_i, σ_i, and $\omega_{0,i}$ calibrated at the state level. Note that the means across all states of the mean and volatility of consumption growth in the simulated data are very close to the means in the real data in Table 2. Also note that the mean across all states of mean growth in housing wealth is 1.13% in simulated data and is 1.17% in Table 2. The calibration, however, generates housing price volatility (which we do not target) smaller than that observed in the actual data.

Because our first calibration procedure results in housing price volatilities smaller than those observed in the data, we need to assess the robustness of our conclusion to this calibration shortcoming. To do so, we implement a second calibration procedure in which we choose the parameter $\omega_{0,i}$ for each state i to match the volatility – as opposed to the mean – in housing wealth. Panel B of Table 6 displays the results of this calibration. This calibration still matches the moments of consumption growth quite well; however, the mean housing wealth growth in the simulated data is about 1.43% larger than that in the actual data. This worse fit for mean housing wealth growth is the cost of having a better fit for the volatility of housing wealth. The mean volatility in housing wealth growth across all states in the second calibration procedure is 4.05%, which is almost twice as large as that in the first calibration procedure (2.20%) and is closer to the mean volatility in the actual data (6.54%).

We use the calibrated model to simulate 500 different time series of $\{c_{i,t}, k_{i,t}, w^H_{i,t}\}$ where $t \in \{1, 2, \cdots, T\}$ for each state i. We set T equal to 30 and assume that we observe annual consumption growth, non-housing capital growth and housing wealth growth, all measured with error. As mentioned in Section 2, the noise terms $\varepsilon^c_{i,t}, \varepsilon^k_{i,t}$ and $\varepsilon^H_{i,t}$ are normally distributed with mean zero and variances $\sigma^2_{i,\widetilde{c}}$, $\sigma^2_{i,\widetilde{k}}$, and $\sigma^2_{i,\widetilde{H}}$ respectively. The noise terms are independent of each other over time and of shocks to non-housing capital.

[21]See Appendix B for details of this simulation. Appendix C gives details of the calibration.

Using the data obtained from each simulation, we estimate panel regressions to assess the housing wealth effect using the specification

$$\Delta\widetilde{c}_{i,t} = \alpha_i + \beta_{w^H}\Delta\widetilde{w}^H_{i,t} + \beta_k\Delta\widetilde{k}_{i,t} + \epsilon_{i,t}. \tag{7}$$

These panel regressions are analogous to the ones in Section 2. Recall that in the simulated model, variations in the log of non-housing capital (k) drive variations in both the log of non-housing consumption (c) and in the log of housing wealth (w^H). If observed without any measurement errors, the common factor (k) would explain the variation in non-housing consumption nearly perfectly. However, since our goal is to use the simulations to gauge the extent that an omitted variable bias can explain the observed elasticity of consumption to housing wealth, we assume that we observe only a noisy proxy for Δk.

Equation 2 indicates that the estimated elasticity of consumption to housing wealth depends on the noise-to-signal ratios of the growth in the omitted variable and of housing price appreciation. These noise-to-signal ratios are ultimately unknown. We therefore provide results for a range of noise-to-signal ratios of the variables used in the analysis.

Specifically, we follow a two-pronged approach to assess the errors in the empirically-observed proxies that are needed to generate the estimates using historical data. First, since the regression R^2s and the T-statistics of the coefficients depend on the magnitude of the errors in all the variables, we change the noise-to-signal ratios equally for all the variables. Second, since the magnitude of the coefficient β_{w^H} depends only on the noise-to-signal ratios of Δw^H and Δk (see Equation 2), we allow $\sigma^2_{\widetilde{k}}/\sigma^2_k$ and $\sigma^2_{\widetilde{H}}/\gamma^2_{w^H}\sigma^2_k$ to be different from each other, and compare the coefficients estimated using simulated data to those obtained in historical data. Although the number of possible permutations of the noise-to-signal ratios of the three variables ($\Delta c, \Delta w^H$ and Δk) can become unmanageably large, our two-pronged approach results in a parsimonious picture of the effects of omitted variable biases in the estimation of the elasticity of consumption to housing wealth.

Panel A of Table 7 displays the results of the analysis when the noise-to-signal ratio is zero, that is, when we observe the underlying variables without any measurement errors. This panel shows the baseline of the housing wealth effects in the model. The first column shows the results of the panel data regression of $\Delta\widetilde{w}^H$ on $\Delta\widetilde{k}$. This specification confirms that changes in housing wealth are positively correlated with changes in non-housing capital in this model. The R^2 in this specification is about 61%, which indicates that even when there are no measurement errors, variation in non-housing capital cannot perfectly explain changes in housing wealth. This result is consistent with the fact that housing prices are a non-linear function of k in the model (see Panel B of Figure 1). In Specifications 1 to 3 of Table 7, $\Delta\widetilde{c}$ is the dependent variable. Specification 1 shows that $\Delta\widetilde{w}^H$ explains some of the variation in $\Delta\widetilde{c}$ when $\Delta\widetilde{k}$ is not controlled for. Specification 2 shows that $\Delta\widetilde{k}$ explains nearly all of the variation in $\Delta\widetilde{c}$. In fact, the R^2 in Specification 2 is almost one (99.74%). Specification 3 shows that even though $\Delta\widetilde{k}$ almost completely explains variations in $\Delta\widetilde{c}$, $\Delta\widetilde{w}^H$ plays a very small role in explaining such variations due to the fact that c is not a perfectly linear function of k (see Panel A in Figure 1). However the incremental explanatory power of $\Delta\widetilde{w}^H$ is very small. Indeed, the R^2 in Specification 3 is only 0.01% larger than that in Specification 2.

Panels B, C, and D of Table 7 show the results of the simulated panel regressions with noise-to-signal ratios of 50%, 100% and 150%, respectively. These results indicate that noise-to-signal ratios of around 150% are required to match the R^2s and T-statistics obtained using historical data. While a noise-to-signal ratio of 150% could be considered implausibly high, it is interesting to note that the housing wealth effects estimated when using such large level of noise are around 37%, which is much higher than the 13% observed in the data. The results also indicate that for any of the considered non-zero noise-to-signal ratios, the estimated elasticity of consumption to housing wealth effect (β_{w^H}) is around 40% which is much larger than that estimated using historical data. These large estimates of the elasticity of consumption to housing wealth indicate that when measurement errors are large, the omitted variable bias in the estimation of housing wealth effects is very large.

It is interesting to note that the results in Table 7 are consistent with the attenuation bias commonly described in the literature.[22] To see this, note that the coefficients in the univariate specifications decrease as the noise-to-signal ratio increase across the panels in Table 7. At first glance, the only result that is not consistent with the classic attenuation

[22] The attenuation bias has received attention in the wealth effects literature (e.g. Brunnermeier and Nagel (2008), Juster, Lupton, Smith, and Stafford (2006), and Filmer and Pritchett (2001)).

bias is the increase in the point estimate of β_{w^H} from Panel A to Panel B. To understand this apparent inconsistency, note that the attenuation bias is a result related to measurement error in *one* independent variable (see Wooldridge (2010)) while the measurement errors of *two* independent variables change between Panels A and B of Table 7. The intuition for the increase in β_{w^H} from Panel A to Panel B is as follows. In Panel A, growth in housing wealth plays a very small role explaining consumption growth because growth in non-housing capital almost completely determines consumption growth in the model. On the other hand, in Panel B, both $\Delta\widetilde{w}^H$ and $\Delta\widetilde{k}$ are noisy proxies for the true variation in non-housing capital and hence they both contribute to explaining consumption growth.

Recall that our calibrations do not generate the same level of housing wealth volatility as that in the actual data. The results in Table 8 – which display the results of simulations based on the calibration of the model designed to match the volatility rather than the mean of housing wealth (see Panel B of Table 6) – indicate that this calibration shortcoming does not make a qualitative difference to the results. Even though the volatility of housing wealth doubles from Table 7 to Table 8, the central message from this analysis carries through: when measurement errors are large, the omitted variable bias in the estimation of housing wealth effects is very large. However, as examine in greater detail below, the elasticity of consumption to housing wealth remains high for even small errors in variables.

To gain further intuition about the size of the noise-to-signal ratios that could generate estimates of β_{w^H} close to those observed in the literature, we turn to Figure 2, which shows that a large, and statistically significant, housing wealth effect is estimated in panel regressions even when measurement errors in all the variables are fairly small. Figure 2 plots the mean estimate across the 500 simulations of the elasticity of consumption to housing wealth (β_{w^H}) against the noise-to-signal ratio of $\Delta\widetilde{c}$, $\Delta\widetilde{w}^H$, and $\Delta\widetilde{k}$ used in the simulations. β_{w^H} increases very sharply when the errors in variables are small (see the inset figure on the bottom-left part of the graph). An increase from 0% to 1% in the noise-to-signal ratio of $\Delta\widetilde{c}$, $\Delta\widetilde{w}^H$, $\Delta\widetilde{k}$ increases β_{w^H} by 4%. The mean estimate of β_{w^H} for a noise-to-signal ratio of 3% is 11.9%, close to the estimate in the historical data (see Table 4). In the second part of our analysis, we therefore restrict the noise-to-signal ratios in the two variables of interest to lie between 5% and 30%.

The relation between $\Delta\widetilde{w}^H$ and $\Delta\widetilde{k}$ in the calibrated model combined with even small errors in $\Delta\widetilde{k}$ are sufficient to generate housing wealth effects larger than those observed in the data. Note in Table 9 that even with a noise-to-signal ratio of 5% in $\Delta\widetilde{k}$, the average point estimate of β_{w^H} is around 15%. In other words, our simulation results indicate that it is easy to generate economically large housing wealth effects when the common factor that is the sole driver of housing price and consumption growth is measured with error. Table 10, which presents results when $\omega_{0,i}$ is chosen to match the volatility of housing price growth, shows that the above conclusions are not due to the model's inability to generate sufficiently volatile housing price growth.

Overall, our results suggest that a large amount of the housing wealth effect estimated at the state level can be explained by the omitted variable bias. Our simple structural model can generate large wealth effects that are consistent with or even larger than those in the data despite omitting other mechanisms suggested in the literature, such as the relaxation of collateral constraints. Our structural model is a fairly simplified version of reality, and a large literature examining the equity premium puzzle show that consumption models based on simple power utility normally do not match some of the asset returns moments well. However, our results suggest that matching model-generated β_{w^H} with the values that we observe in the actual data is not a problem for models based on simple power utility as long as housing is inelastic and a perfect proxy for the common factor that drives both non-housing consumption and demand for housing is not available.

5 Conclusion

Our simulated model can easily generate housing wealth effects that are consistent with or even larger than those observed in the data despite omitting other mechanisms suggested in the literature, such as the relaxation of collateral constraints. In fact, the mechanism by which the model generates large housing wealth effects relies only on two generally accepted premises. First, that housing cannot be converted into non-housing consumption in the aggregate. And second, that econometricians can only observe noisy proxies of the variables affecting consumption and housing prices.

Our results indicate that an omitted variable bias possibly accounts for a large portion of the estimated elasticity of consumption with respect to housing wealth. Naturally, our results do not discard the causal relation between growth in housing wealth and consumption growth operating through other mechanisms explored in the literature. Our simulations, however, show that even when we control for the common variable driving consumption with a very precise – but imperfect – proxy, we find quite large elasticities of consumption to housing wealth. In fact, even when about 95% of the variation of the omitted variable is explained by its proxy, we obtain elasticities of consumption to housing wealth that are well within the range of the elasticities estimated in the literature. Our results therefore highlight the importance of further research into techniques and instruments that address the omitted variable bias when estimating the elasticity of consumption to housing wealth.

References

Abdallah, Chadi S., and William D. Lastrapes, 2012, Home equity lending and retail spending: Evidence from a natural experiment in Texas, *American Economic Journal: Macroeconomics* 4, 94–125.

Agarwal, Sumit, 2007, The impact of homeowners' housing wealth misestimation on consumption and saving decisions, *Real Estate Economics* 35, 135–154.

———, and Wenlan Qian, 2017, Access to home equity and consumption: Evidence from a policy experiment, *Review of Economics and Statistics* 99, 40–52.

Aladangady, Aditya, 2017, Housing wealth and consumption: Evidence from geographically-linked microdata, *American Economic Review* 107, 3415–46.

Attanasio, Orazio P., Laura Blow, Robert Hamilton, and Andrew Leicester, 2009, Booms and busts: Consumption, house prices and expectations, *Economica* 76, 20–50.

Benítez-Silva, Hugo, Selçuk Eren, Frank Heiland, and Sergi Jiménez-Martín, 2015, How well do individuals predict the selling prices of their homes?, *Journal of Housing Economics* 29, 12–25.

Benjamin, John D., Peter Chinloy, and G. Donald Jud, 2004, Real estate versus financial wealth in consumption, *Journal of Real Estate Finance and Economics* 29, 341–354.

Bostic, Raphael, Stuart Gabriel, and Gary Painter, 2009, Housing wealth, financial wealth, and consumption: New evidence from micro data, *Regional Science and Urban Economics* 39, 79–89.

Brunnermeier, Markus K., and Stefan Nagel, 2008, Do wealth fluctuations generate time-varying risk aversion? Micro-evidence on individuals asset allocation, *American Economic Review* 98, 713–736.

Calomiris, Charles W., Stanley D. Longhofer, and William Miles, 2009, The (mythical?) housing wealth effect, *NBER Working Paper No. 15075.*

——— , 2012, The housing wealth effect: The crucial roles of demographics, wealth distribution and wealth shares, *Critical Finance Review* 2, 49–99.

Campbell, John, and Angus Deaton, 1989, Why is consumption so smooth?, *Review of Economic Studies* 56, 357–374.

Campbell, John Y., and Joao F. Cocco, 2007, How do house prices affect consumption? Evidence from micro data, *Journal of Monetary Economics* 54, 591–621.

Campbell, John Y., and Gregory N. Mankiw, 1990, Permanent income, current income, and consumption, *Journal of Business & Economic Statistics* 8, 265–279.

Carroll, Christopher D., Misuzu Otsuka, and Jiri Slacalek, 2011, How large are housing and financial wealth effects? A new approach, *Journal of Money, Credit and Banking* 43, 55–79.

Case, Karl E., John M. Quigley, and Robert J. Shiller, 2005, Comparing wealth effects: The stock market versus the housing market, *Advances in Macroeconomics* 5, 1–32.

——— , 2013, Wealth effects revisited 1975-2012, *Critical Finance Review* 2, 101–128.

Chen, Hui, Michael Michaux, and Nikolai Roussanov, 2013, Houses as ATMs? Mortgage refinancing and macroeconomic uncertainty, *NBER Working Paper No. 19421.*

Cocco, Joao F., 2005, Portfolio choice in the presence of housing, *Review of Financial Studies* 18, 535–567.

DeFusco, Anthony A, 2018, Homeowner borrowing and housing collateral: New evidence from expiring price controls, *Journal of Finance* 73, 523–573.

Di Giovanni, Julian, and Akito Matsumoto, 2011, The value of human capital wealth, *Global COE Hi-Stat Discussion Paper Series 174*.

Dvornak, Nikola, and Marion Kohler, 2007, Housing wealth, stock market wealth and consumption: A panel analysis for Australia, *Economic Record* 83, 117–130.

Fan, Ying, and Abdullah Yavas, 2018, How does mortgage debt affect household consumption? Micro evidence from China, *Real Estate Economics, forthcoming*.

Filmer, Deon, and Lant H. Pritchett, 2001, Estimating wealth effects without expenditure data or tears: An application to educational enrollments in states of india, *Demography* 38, 115–132.

Flavin, Marjorie, and Shinobu Nakagawa, 2008, A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence, *American Economic Review* 98, 474–495.

Follain, James R., and Stephen Malpezzi, 1981, Are occupants accurate appraisers?, *Review of Public Data Use* 9, 47–55.

Gan, Jie, 2010, Housing wealth and consumption growth: Evidence from a large panel of households, *Review of Financial Studies* 23, 2229–2267.

Geltner, David M., Norman G. Miller, Jim Clayton, and Piet Eichholtz, 2013, *Commercial Real Estate Analysis & Investments* (Thomson South-Western).

Goodman, John L., and John B. Ittner, 1992, The accuracy of home owners' estimates of house value, *Journal of Housing Economics* 2, 339–357.

Guerrieri, Luca, and Matteo Iacoviello, 2017, Collateral constraints and macroeconomic asymmetries, *Journal of Monetary Economics* 90, 28–49.

Guren, Adam M., Alisdair McKayy, Emi Nakamura, and Jon Steinsson, 2018, Housing wealth effects: The long view, *NBER Working Paper No. 24729*.

Gyourko, Joseph, Albert Saiz, and Anita Summers, 2008, A new measure of the local regulatory environment for housing markets: The wharton residential land use regulatory index, *Urban Studies* 45, 693–729.

Hall, Robert E., 1988, Intertemporal substitution in consumption, *Journal of Political Economy* 96, 339–357.

Harding, John P., Stuart S. Rosenthal, and C.F. Sirmans, 2007, Depreciation of housing capital, maintenance, and house price inflation: Estimates from a repeat sales model, *Journal of Urban Economics* 61, 193–217.

Iacoviello, Matteo, 2005, House prices, borrowing constraints, and monetary policy in the business cycle, *American Economic Review* 95, 739–764.

——— , 2012, Housing wealth and consumption, in Susan J. Smith, ed.: *International Encyclopedia of Housing and Home* . pp. 673–678 (Elsevier: San Diego).

——— , and Stefano Neri, 2010, Housing market spillovers: Evidence from an estimated DSGE model, *American Economic Journal: Macroeconomics* 2, 125–164.

Ihlanfeldt, Keith R., and Jorge Martinez-Vazquez, 1986, Alternative value estimates of owner-occupied housing: Evidence on sample selection bias and systematic errors, *Journal of Urban Economics* 20, 356–369.

Jorgenson, Dale W., and Barbara M. Fraumeni, 1989, The accumulation of human and nonhuman capital, 1948-84, in Robert E. Lipsey, and Helen S. Tice, ed.: *The Measurement of Saving, Investment, and Wealth* . pp. 227–286 (University of Chicago Press: Chicago).

Juster, F. Thomas, Joseph P. Lupton, James P. Smith, and Frank Stafford, 2006, The decline in household saving and the wealth effect, *Review of Economics and Statistics* 88, 20–27.

Justiniano, Alejandro, Giorgio E Primiceri, and Andrea Tambalotti, 2015, Household leveraging and deleveraging, *Review of Economic Dynamics* 18, 3–20.

Kain, John F, and John M Quigley, 1972, Note on owner's estimate of housing value, *Journal of the American Statistical Association* 67, 803–806.

Kiel, Katherine A., and Jeffrey E. Zabel, 1999, The accuracy of owner-provided house values: The 1978–1991 American Housing Survey, *Real Estate Economics* 27, 263–298.

Kish, Leslie, and John B Lansing, 1954, Response errors in estimating the value of homes, *Journal of the American Statistical Association* 49, 520–538.

Knight, John R, and CF Sirmans, 1996, Depreciation, maintenance, and housing prices, *Journal of Housing Economics* 5, 369–389.

Kogan, Leonid, 2001, An equilibrium model of irreversible investment, *Journal of Financial Economics* 62, 201–245.

———, 2004, Asset prices and real investment, *Journal of Financial Economics* 73, 411–431.

Labhard, Vincent, Gabriel Sterne, and Chris Young, 2005, The wealth effects on consumption in industrialized countries, *Bank of England Working paper No. 275.*

Leigh, Wilhelmina A., 1980, Economic depreciation of the residential housing stock of the United States, 1950-1970, *Review of Economics and Statistics* 62, 200–206.

Leth-Petersen, Søren, 2010, Intertemporal consumption and credit constraints: Does total expenditure respond to an exogenous shock to credit?, *American Economic Review* 100, 1080–1103.

Ludwig, Alexander, and Torsten Sløk, 2002, The impact of changes in stock prices and house prices on consumption in OECD countries, *IMF Working Paper No. WP/02/1.*

Lustig, Hanno, Stijn Van Nieuwerburgh, and Adrien Verdelhan, 2013, The wealth-consumption ratio, *Review of Asset Pricing Studies* 3, 38–94.

Lustig, Hanno N., and Stijn G. Van Nieuwerburgh, 2005, Housing collateral, consumption insurance, and risk premia: An empirical perspective, *Journal of Finance* 60, 1167–1219.

Malpezzi, Stephen, Larry Ozanne, and Thomas G. Thibodeau, 1987, Microeconomic estimates of housing depreciation., *Land Economics* 63, 372–385.

Mian, Atif, Kamalesh Rao, and Amir Sufi, 2013, Household balance sheets, consumption, and the economic slump, *Quarterly Journal of Economics* 128, 1687–1726.

Mishkin, Frederic S., 2007, Housing and the monetary transmission mechanism, in *Housing, Housing Finance, and Monetary Policy, 2007 Jackson Hole Symposium* . pp. 359–413 (Federal Reserve Bank of Kansas City).

Moore, Jeffrey C.and Stinson, Linda L., and Edward J. Welniak, 2000, Income measurement error in surveys: A review., *Journal of Official Statistics* 16, 331–361.

Muellbauer, John N., 2007, Housing credit and consumer expenditure, in *Housing, Housing Finance, and Monetary Policy, 2007 Jackson Hole Symposium* . pp. 267–334 (Federal Reserve Bank of Kansas City).

Paiella, Monica, 2009, The stock market, housing and consumer spending: A survey of the evidence on wealth effects, *Journal of Economic Surveys* 23, 947–973.

Palacios, Miguel, 2015, Human capital as an asset class implications from a general equilibrium model, *Review of Financial Studies* 28, 978–1023.

Piazzesi, Monika, Martin Schneider, and Selale Tuzel, 2007, Housing, consumption and asset pricing, *Journal of Financial Economics* 83, 531–569.

Robins, Philip K, and Richard W West, 1977, Measurement errors in the estimation of home value, *Journal of the American Statistical Association* 72, 290–294.

Saiz, Albert, 2010, The geographic determinants of housing supply, *Quarterly Journal of Economics* 125, 1253–1296.

Shilling, James D., C.F. Sirmans, and Jonathan F. Dombrow, 1991, Measuring depreciation in single-family rental and owner-occupied housing, *Journal of Housing Economics* 1, 368–383.

Wooldridge, Jeffrey M., 2010, *Econometric Analysis of Cross Section and Panel Data* (MIT Press).

Zhou, Xia, 2010, *Essays on US state-level financial wealth data and consumption data* (Johns Hopkins University Dissertation).

——— , and Christopher Carroll, 2012, Dynamics of wealth and consumption: New and improved measures for US states, *The B.E. Journal of Macroeconomics* 12, 1–44.

Table 1: **Variable Definitions.** This table contains the description and sources of all data variables used in this paper.

Variable name	Variable definition
Δc	Difference between the log aggregate real non-housing consumption between years $t-1$ and t. At state level, this is calculated by adding the log growth in population to the estimates of real non-housing consumption growth in Zhou (2010), which is available since 1971 for most of states with exception of Alaska, Delaware, Montana, Nevada, New Hampshire and Oregon which have consumption growth data available from 1998 onwards.
CPI	US-level consumer price index. Source: http://www.bls.gov/cpi/#tables
$FHFA\_index$	All-transactions FHFA house price index for US states. All-transactions indices augment purchase-only data with appraisal data; see original data source for details. Source: http://www.fhfa.gov/DataTools/Downloads/pages/house-price-index.aspx.
Δw^H	Difference in the logarithm of aggregate house price index between years $t-1$ and t. The aggregate house price index is obtained by multiplying the $FHFA\_index$ by the aggregate number of households. The number of households in year t is obtained by dividing the total population in a region in year t by the average household size in the region in year t. Data on the population and average household size are both provided by the US census bureau. The aggregate nominal housing index is then deflated by CPI. Sources: Population and persons per household available from http://www.census.gov/geography.html.
Δy	Difference between the logarithm of real aggregate income at year $t+1$ and at year t in state i. Total real income is obtained by deflating the estimate of the total nominal income – obtained from the Bureau of Economic Analysis – by CPI. Source: http://www.bea.gov/regional/downloadzip.cfm
w^{TR}_{US}	Total nominal tradeable assets in the United States. Obtained by adding the following item lines from the Federal Reserve Flow of Accounts: corporate equities, mutual fund shares and private pension fund reserves. Source: http://www.federalreserve.gov/releases/z1/Current/data.htm
CDI	Cummulative disposible income for each state between 1960 and year t. $CDI_{i,t}$ for state i at year t is the sum of the total disposable income for state i for every year between 1960 and t. The $CDI_{i,t}$ calculation starts in 1960 because this is the first year that income data are available for every state. Sources: Historical series of disposable income for states are in Table SA51 of the US Bureau of Economic Analysis. http://www.bea.gov/itable/iTable.cfm?ReqID=70&step=1#reqid=70&step=1&isuri=1
Δw^{TR}	Difference between the logarithm of real non-housing tradable wealth year $t-1$ and t. Real per-capita non-housing wealth in state i in year t is obtained by $Total^{TR} \times CDI_{i,t} / \sum_{i=1}^{50} CDI_{i,t}$ deflated by CPI.

Table 2: **Summary Statistics.** This table contains the mean and standard deviation (Std. Dev.) of the real annual log-growth of aggregated non-housing consumption (Δc), housing wealth (Δw^H), non-housing tradable wealth (Δw^{TR}), and income (Δy) for all U.S. states and the District of Columbia. Details of variable construction are specified in Table 1. The sample consists of annual observations from 1976–2012, with the exception that non-housing consumption growth data begin in 1998 for Alaska, Delaware, Montana, Nevada, New Hampshire, and Oregon.

	Δc		Δw^H		Δw^{TR}		Δy	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
AL	1.25	2.69	0.57	3.80	5.01	12.98	1.49	1.90
AK	2.04	1.92	1.07	9.49	4.26	12.74	0.16	2.92
AZ	0.39	4.97	1.04	8.74	4.43	12.83	1.0	2.50
AR	1.06	3.62	0.50	4.63	5.01	12.97	1.53	2.26
CA	1.46	3.84	2.32	9.95	4.33	12.93	1.11	2.28
CO	1.61	4.40	1.50	5.10	4.66	12.95	1.35	2.14
CT	2.51	8.68	1.85	8.18	5.03	13.04	1.78	2.63
DE	1.49	1.39	1.43	6.02	4.43	12.90	1.13	1.99
DC	3.08	5.71	3.49	8.72	4.72	12.93	1.94	2.54
FL	1.13	3.52	0.59	7.98	4.84	13.00	1.24	2.33
GA	1.24	3.79	0.01	3.96	4.63	12.94	1.38	2.39
HI	2.24	5.27	3.70	16.79	4.36	13.04	0.78	2.09
ID	0.72	4.16	0.55	6.19	4.34	12.97	0.96	2.42
IL	0.47	3.78	0.68	5.67	4.63	12.93	1.16	2.17
IN	0.65	5.36	0.29	3.38	4.57	12.93	1.17	2.48
IA	0.93	4.39	0.27	4.44	4.71	12.93	1.37	3.04
KS	1.31	4.38	0.06	3.55	4.63	12.94	1.27	2.04
KY	2.43	4.36	0.63	3.49	4.88	12.95	1.40	1.98
LA	1.68	5.41	0.80	4.39	5.17	13.16	1.71	2.28
ME	2.17	4.51	2.02	7.27	5.00	13.13	1.63	2.14
MD	1.50	5.07	1.68	6.56	4.85	12.99	1.51	1.84
MA	3.23	6.39	2.70	8.14	5.02	13.04	1.91	2.43
MI	1.31	6.34	0.55	6.13	4.68	12.92	1.00	2.75
MN	1.55	6.18	1.07	5.19	4.78	12.96	1.55	2.44
MS	0.79	3.24	0.10	4.62	5.10	12.96	1.64	1.88
MO	0.37	4.02	0.48	4.22	4.63	12.95	1.23	1.88
MT	2.36	1.53	1.77	6.01	4.38	12.97	1.14	2.38
NE	1.10	6.51	0.13	3.68	4.72	12.95	1.41	2.68
NV	1.02	2.90	0.10	9.66	3.92	12.94	0.62	2.82
NH	1.89	1.47	2.10	9.39	5.24	13.14	1.90	2.56
NJ	1.59	3.79	2.09	7.74	4.92	12.98	1.61	2.22
NM	1.66	5.06	1.09	4.83	4.55	12.88	1.24	1.64
NY	1.29	3.02	1.96	6.97	4.68	12.98	1.58	2.31
NC	2.21	5.11	0.70	3.46	4.74	13.00	1.48	2.21
ND	1.74	5.18	1.17	7.32	4.64	12.94	2.06	6.97
OH	2.64	3.46	0.25	3.86	4.65	12.97	1.18	2.05
OK	1.52	4.52	0.14	4.57	4.73	12.90	1.45	2.61
OR	1.41	2.32	1.78	7.85	4.48	12.99	1.02	2.29
PA	2.00	3.99	1.13	4.99	4.84	12.99	1.45	1.62
RI	1.48	4.93	2.06	8.92	4.85	13.06	1.60	2.06
SC	1.75	6.14	0.90	3.21	4.83	12.99	1.40	1.91
SD	2.35	4.12	0.95	7.36	4.73	12.88	1.70	4.09
TN	1.24	4.04	0.46	3.54	4.95	12.98	1.58	2.24
TX	1.27	3.61	0.13	3.80	4.59	12.89	1.46	2.42
UT	3.02	9.56	0.92	6.19	4.24	12.98	1.25	2.27
VT	2.64	5.41	2.72	15.26	5.17	13.08	1.86	2.22
VA	1.31	3.46	1.48	5.49	4.86	13.02	1.57	1.79
WA	1.72	5.46	2.13	6.97	4.51	12.98	1.29	2.22
WV	1.32	8.02	0.13	7.56	4.94	13.01	1.38	1.70
WI	1.83	5.69	0.76	5.16	4.77	12.98	1.34	1.92
WY	1.09	7.03	1.06	6.21	4.82	13.05	1.58	3.76

Table 3: **Correlation of Consumption Growth.** This table presents the correlation of real annual log-growth of aggregated non-housing consumption (Δc) between states in the United States. The sources and details of variable construction are specified in Table 1. Data for the period 1998–2012 are used for estimating the sample correlations.

	AL	AK	AZ	AR	CA	CO	CT	DE	DC	FL	GA	HI	ID	IL	IN	IA	KS
AK	0.54																
AZ	0.80	0.40															
AR	0.69	0.41	0.83														
CA	0.77	0.51	0.95	0.84													
CO	0.58	0.54	0.77	0.82	0.85												
CT	0.82	0.42	0.90	0.69	0.90	0.77											
DE	0.84	0.78	0.78	0.65	0.78	0.73	0.81										
DC	0.51	0.45	0.45	0.14	0.52	0.27	0.52	0.44									
FL	0.75	0.43	0.89	0.70	0.80	0.69	0.77	0.76	0.44								
GA	0.77	0.49	0.89	0.91	0.93	0.91	0.85	0.76	0.27	0.75							
HI	-0.32	0.01	-0.31	-0.56	-0.44	-0.39	-0.37	-0.09	-0.22	-0.10	-0.46						
ID	0.78	0.55	0.91	0.88	0.92	0.82	0.82	0.80	0.38	0.84	0.90	-0.41					
IL	0.70	0.36	0.84	0.82	0.89	0.81	0.79	0.59	0.50	0.81	0.87	-0.60	0.86				
IN	0.81	0.54	0.85	0.86	0.89	0.86	0.87	0.82	0.39	0.81	0.91	-0.50	0.87	0.88			
IA	0.55	0.23	0.70	0.83	0.73	0.74	0.68	0.49	0.22	0.53	0.75	-0.78	0.71	0.80	0.79		
KS	0.58	0.45	0.84	0.82	0.88	0.94	0.81	0.71	0.24	0.75	0.90	-0.40	0.83	0.84	0.86	0.80	
KY	0.80	0.61	0.72	0.67	0.70	0.73	0.83	0.88	0.32	0.70	0.76	-0.30	0.77	0.65	0.82	0.62	0.73
LA	0.13	0.02	0.48	0.26	0.45	0.27	0.37	0.19	0.35	0.54	0.27	-0.18	0.54	0.50	0.29	0.32	0.42
ME	0.61	0.52	0.73	0.63	0.68	0.71	0.78	0.74	0.25	0.70	0.69	-0.11	0.64	0.59	0.74	0.55	0.75
MD	0.67	0.61	0.86	0.79	0.83	0.88	0.75	0.80	0.37	0.87	0.84	-0.11	0.82	0.77	0.80	0.60	0.85
MA	0.61	0.49	0.82	0.80	0.85	0.88	0.74	0.68	0.37	0.77	0.85	-0.28	0.82	0.82	0.83	0.65	0.82
MI	0.63	0.47	0.72	0.90	0.81	0.88	0.74	0.66	0.17	0.56	0.90	-0.67	0.84	0.80	0.88	0.87	0.85
MN	0.63	0.75	0.70	0.74	0.78	0.89	0.75	0.84	0.26	0.66	0.85	-0.26	0.80	0.69	0.84	0.59	0.86
MS	0.77	0.47	0.83	0.74	0.79	0.73	0.86	0.81	0.35	0.80	0.79	-0.37	0.91	0.76	0.82	0.68	0.78
MO	0.62	0.62	0.61	0.65	0.77	0.81	0.76	0.70	0.44	0.45	0.80	-0.56	0.68	0.71	0.79	0.67	0.78
MT	0.76	0.64	0.72	0.49	0.80	0.64	0.86	0.83	0.59	0.63	0.71	-0.25	0.72	0.64	0.73	0.48	0.71
NE	0.65	0.68	0.78	0.81	0.83	0.85	0.78	0.87	0.26	0.66	0.83	-0.33	0.87	0.67	0.86	0.70	0.85
NV	0.81	0.47	0.94	0.72	0.86	0.69	0.86	0.87	0.42	0.86	0.78	-0.08	0.84	0.65	0.77	0.53	0.73
NH	0.70	0.76	0.75	0.82	0.78	0.89	0.73	0.88	0.28	0.72	0.84	-0.25	0.83	0.70	0.86	0.67	0.83
NJ	0.70	0.65	0.85	0.64	0.90	0.79	0.82	0.77	0.65	0.81	0.81	-0.17	0.83	0.81	0.77	0.47	0.78
NM	0.58	0.50	0.78	0.58	0.79	0.65	0.72	0.70	0.47	0.72	0.66	-0.22	0.76	0.70	0.67	0.57	0.77
NY	0.79	0.48	0.88	0.85	0.87	0.87	0.89	0.80	0.35	0.86	0.91	-0.40	0.91	0.88	0.94	0.72	0.86
NC	0.69	0.33	0.86	0.90	0.89	0.89	0.84	0.66	0.27	0.74	0.93	-0.55	0.89	0.88	0.90	0.79	0.86
ND	0.28	0.09	0.06	0.32	0.21	0.13	0.12	0.15	-0.04	0.06	0.27	-0.59	0.25	0.31	0.41	0.34	0.18
OH	0.68	0.66	0.74	0.82	0.82	0.89	0.75	0.77	0.27	0.72	0.90	-0.35	0.82	0.80	0.90	0.63	0.86
OK	0.54	0.13	0.68	0.68	0.72	0.62	0.61	0.45	0.26	0.58	0.68	-0.56	0.72	0.76	0.69	0.75	0.69
OR	0.62	0.19	0.88	0.86	0.88	0.67	0.74	0.50	0.37	0.71	0.80	-0.59	0.83	0.86	0.78	0.82	0.76
PA	0.71	0.75	0.81	0.79	0.83	0.90	0.80	0.91	0.35	0.76	0.85	-0.20	0.86	0.72	0.86	0.62	0.86
RI	0.79	0.65	0.79	0.79	0.78	0.67	0.67	0.78	0.46	0.71	0.77	-0.30	0.84	0.70	0.73	0.52	0.62
SC	0.84	0.45	0.88	0.80	0.87	0.77	0.93	0.79	0.42	0.78	0.86	-0.46	0.90	0.83	0.89	0.74	0.78
SD	0.65	0.36	0.67	0.76	0.70	0.51	0.65	0.59	0.19	0.42	0.67	-0.63	0.70	0.58	0.68	0.76	0.61
TN	0.87	0.47	0.87	0.89	0.86	0.78	0.87	0.78	0.33	0.78	0.91	-0.54	0.90	0.86	0.92	0.80	0.80
TX	0.64	0.41	0.66	0.82	0.74	0.89	0.68	0.64	0.08	0.60	0.89	-0.50	0.75	0.79	0.86	0.76	0.84
UT	0.64	0.21	0.93	0.75	0.89	0.77	0.84	0.62	0.48	0.85	0.80	-0.40	0.81	0.88	0.79	0.73	0.86
VT	0.65	0.09	0.66	0.48	0.62	0.35	0.63	0.39	0.52	0.56	0.50	-0.37	0.54	0.62	0.53	0.57	0.39
VA	0.80	0.69	0.83	0.75	0.87	0.90	0.87	0.89	0.49	0.76	0.89	-0.29	0.85	0.78	0.86	0.62	0.83
WA	0.55	0.37	0.73	0.73	0.77	0.89	0.79	0.62	0.31	0.69	0.80	-0.49	0.71	0.84	0.86	0.82	0.92
WV	0.53	0.57	0.36	0.50	0.40	0.53	0.49	0.50	0.20	0.31	0.54	-0.44	0.50	0.49	0.53	0.55	0.49
WI	0.76	0.48	0.97	0.83	0.94	0.81	0.91	0.80	0.47	0.85	0.87	-0.36	0.92	0.84	0.85	0.75	0.87
WY	0.64	0.36	0.81	0.63	0.82	0.66	0.79	0.67	0.44	0.66	0.70	-0.36	0.80	0.71	0.69	0.70	0.75

Continued on next page

	KY	LA	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC
LA	0.23																
ME	0.84	0.20															
MD	0.73	0.30	0.80														
MA	0.57	0.28	0.64	0.88													
MI	0.74	0.24	0.61	0.69	0.76												
MN	0.86	0.23	0.80	0.82	0.71	0.81											
MS	0.91	0.57	0.73	0.72	0.64	0.77	0.78										
MO	0.76	0.15	0.64	0.62	0.57	0.82	0.87	0.67									
MT	0.79	0.34	0.68	0.62	0.53	0.58	0.78	0.75	0.83								
NE	0.80	0.29	0.75	0.78	0.80	0.86	0.88	0.81	0.75	0.72							
NV	0.74	0.38	0.72	0.82	0.74	0.61	0.67	0.81	0.51	0.71	0.78						
NH	0.85	0.18	0.79	0.90	0.80	0.84	0.92	0.78	0.75	0.65	0.91	0.76					
NJ	0.66	0.47	0.68	0.85	0.80	0.62	0.80	0.72	0.73	0.83	0.73	0.78	0.74				
NM	0.59	0.56	0.61	0.70	0.66	0.53	0.66	0.71	0.59	0.80	0.74	0.70	0.60	0.80			
NY	0.88	0.40	0.82	0.85	0.83	0.84	0.85	0.91	0.74	0.72	0.83	0.80	0.85	0.81	0.69		
NC	0.71	0.36	0.67	0.78	0.88	0.91	0.75	0.80	0.70	0.58	0.82	0.74	0.78	0.73	0.60	0.93	
ND	0.18	0.03	-0.10	-0.12	0.05	0.39	0.22	0.21	0.36	0.24	0.23	-0.03	0.11	0.02	0.15	0.22	0.25
OH	0.80	0.21	0.79	0.84	0.80	0.83	0.95	0.74	0.84	0.73	0.84	0.65	0.88	0.81	0.66	0.90	0.83
OK	0.37	0.45	0.22	0.49	0.71	0.67	0.39	0.58	0.43	0.46	0.61	0.55	0.45	0.52	0.68	0.62	0.73
OR	0.47	0.53	0.51	0.67	0.77	0.75	0.50	0.67	0.52	0.50	0.67	0.72	0.59	0.67	0.66	0.75	0.85
PA	0.86	0.26	0.83	0.91	0.84	0.79	0.94	0.81	0.77	0.77	0.94	0.80	0.95	0.84	0.76	0.89	0.80
RI	0.70	0.22	0.63	0.79	0.74	0.65	0.70	0.71	0.61	0.66	0.76	0.75	0.75	0.78	0.72	0.78	0.72
SC	0.83	0.39	0.75	0.75	0.81	0.82	0.73	0.90	0.68	0.74	0.84	0.82	0.78	0.76	0.70	0.93	0.90
SD	0.61	0.23	0.53	0.44	0.48	0.73	0.55	0.67	0.62	0.62	0.75	0.58	0.56	0.45	0.67	0.62	0.65
TN	0.88	0.32	0.76	0.77	0.74	0.87	0.79	0.90	0.74	0.72	0.81	0.78	0.82	0.73	0.66	0.95	0.90
TX	0.67	0.08	0.53	0.70	0.79	0.89	0.77	0.64	0.73	0.54	0.75	0.55	0.78	0.59	0.52	0.81	0.85
UT	0.61	0.59	0.64	0.79	0.76	0.66	0.61	0.76	0.60	0.65	0.65	0.81	0.62	0.80	0.77	0.82	0.83
VT	0.32	0.30	0.25	0.44	0.57	0.43	0.14	0.46	0.22	0.35	0.36	0.60	0.35	0.45	0.37	0.48	0.55
VA	0.86	0.22	0.78	0.89	0.83	0.79	0.90	0.81	0.83	0.81	0.85	0.80	0.90	0.88	0.71	0.90	0.83
WA	0.75	0.32	0.80	0.78	0.76	0.79	0.80	0.73	0.78	0.66	0.75	0.59	0.76	0.69	0.70	0.86	0.82
WV	0.77	0.04	0.61	0.48	0.31	0.64	0.68	0.61	0.71	0.53	0.51	0.27	0.65	0.42	0.32	0.59	0.45
WI	0.78	0.52	0.80	0.87	0.82	0.78	0.76	0.87	0.68	0.76	0.85	0.91	0.81	0.85	0.80	0.89	0.86
WY	0.56	0.53	0.47	0.62	0.72	0.65	0.53	0.73	0.53	0.70	0.76	0.76	0.59	0.69	0.85	0.67	0.71

	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI
OH	0.31															
OK	0.45	0.48														
OR	0.24	0.61	0.80													
PA	0.08	0.91	0.50	0.60												
RI	0.13	0.77	0.50	0.65	0.84											
SC	0.21	0.78	0.70	0.79	0.82	0.77										
SD	0.47	0.58	0.63	0.73	0.61	0.69	0.74									
TN	0.32	0.85	0.65	0.79	0.82	0.81	0.95	0.78								
TX	0.43	0.83	0.73	0.64	0.75	0.57	0.74	0.56	0.79							
UT	0.08	0.67	0.73	0.86	0.70	0.64	0.77	0.55	0.77	0.64						
VT	0.03	0.22	0.67	0.73	0.30	0.39	0.67	0.42	0.57	0.41	0.60					
VA	0.08	0.89	0.53	0.61	0.95	0.84	0.85	0.56	0.85	0.77	0.75	0.41				
WA	0.19	0.84	0.60	0.67	0.80	0.57	0.77	0.56	0.79	0.80	0.81	0.35	0.81			
WV	0.13	0.63	0.11	0.25	0.60	0.51	0.56	0.47	0.68	0.51	0.27	0.13	0.63	0.58		
WI	0.03	0.77	0.64	0.87	0.86	0.79	0.91	0.71	0.89	0.65	0.90	0.63	0.85	0.78	0.48	
WY	0.16	0.52	0.87	0.78	0.68	0.61	0.81	0.70	0.70	0.61	0.78	0.70	0.68	0.62	0.24	0.83

Table 4: **The Housing Wealth Effect in Historical Data.** This table presents the results of panel data regressions of annual aggregated non-housing log-consumption growth (Δc) on the growth of log-housing wealth (Δw^H), and log-income (Δy). State-level fixed effects are included in all specifications and one specification controls for the log of non-housing tradable wealth (Δw^{TR}). β_{w^H} and β_y are the coefficients of the terms Δw^H and Δy, respectively. α is the average of the fixed effect. The value in parentheses below the coefficient is its T-statistic. Overall R^2 (in %) values are reported in the last row. The sample contains observations at annual frequency for the period 1976–2012.

	(1)	(2)	(3)	(4)
β_{w^H}	0.2077		0.1258	0.1266
	(12.16)		(7.27)	(7.28)
β_y		0.7603	0.6416	0.6406
		(16.99)	(13.65)	(13.61)
α	0.0137	0.0053	0.0055	0.0057
	(11.75)	(4.11)	(4.40)	(4.33)
Δw^{TR} control	No	No	No	Yes
R^2	8.26	14.50	17.25	17.26

Table 5: **Model Parameters Common to All States.** This table presents the parameters common to all states in the model calibration.

Parameter	Symbol	Value
House flow services	b	0.100
Rate of depreciation of housing stock	δ	0.013
Time preference	ρ	0.020
Curvature of the utility function	γ	1.200
Productivity of the housing sector	X	0.033

Table 6: **Simulated Data Mean and Standard Deviation.** This table contains the means and standard deviations (Std. Dev.) of the log-growth of annual aggregate consumption (Δc) and of housing wealth (Δw^H) – averaged over 500 simulations of these variables. For each state in each simulation, the numerical solution to the structural model with the parameters α, σ, and ω_0 appropriate to that state is used to generate the evolution of Δc, Δw^H over 30 years. The correlation between shocks to K between states is set equal to the correlation of consumption growth between the corresponding states observed in historical data. The parameters α, σ for each state i are chosen to match the historical mean and volatility of Δc_i. The parameter ω_0 in Panel A (B) is chosen for each state i to match the historical mean (volatility) of Δw_i^H.

	Panel A: ω_0 to match mean housing wealth growth							Panel B: ω_0 to match housing wealth volatility						
	Δc		Δw^H		α	σ	ω_0	Δc		Δw^H		α	σ	ω_0
	Mean	Std. Dev.	Mean	Std. Dev.				Mean	Std. Dev.	Mean	Std. Dev.			
AL	1.25	2.56	0.57	1.03	3.53	2.69	1.34	1.27	2.64	2.56	2.64	3.53	2.69	-0.60
AK	2.04	1.82	1.04	1.22	4.47	1.92	1.48	2.04	1.88	3.17	1.81	4.47	1.92	-0.55
AZ	0.50	4.61	1.05	3.19	2.59	4.97	1.70	0.39	4.83	1.80	5.18	2.59	4.97	-0.56
AR	1.08	3.37	0.47	1.20	3.34	3.62	1.29	1.04	3.53	2.36	3.58	3.34	3.62	-0.60
CA	1.54	3.75	2.33	3.19	3.82	3.84	2.27	1.47	3.79	2.72	3.76	3.82	3.84	-0.56
CO	1.63	4.15	1.50	2.62	4.02	4.40	1.76	1.62	4.28	2.82	4.17	4.02	4.40	-0.57
CT	2.89	8.34	1.85	5.10	5.38	8.68	1.91	2.61	8.38	3.33	7.58	5.38	8.68	-0.60
DE	1.52	1.33	1.41	1.07	3.79	1.39	1.70	1.49	1.36	2.75	1.35	3.79	1.39	-0.56
DC	2.96	5.52	3.47	4.71	5.85	5.71	2.67	3.06	5.53	3.72	4.91	5.85	5.71	-0.59
FL	1.06	3.38	0.58	1.35	3.41	3.52	1.34	1.11	3.44	2.42	3.48	3.41	3.52	-0.58
GA	1.16	3.45	0.01	0.21	3.55	3.79	0.81	1.20	3.67	2.49	3.69	3.55	3.79	-0.58
HI	2.28	5.11	3.29	4.78	4.82	5.27	2.86	2.21	5.10	3.23	4.78	4.82	5.27	-0.56
ID	0.78	3.89	0.57	1.62	2.95	4.16	1.34	0.77	4.02	2.14	4.20	2.95	4.16	-0.55
IL	0.47	3.51	0.71	1.80	2.64	3.78	1.48	0.49	3.70	1.90	3.94	2.64	3.78	-0.58
IN	0.49	5.11	0.31	1.75	2.92	5.36	1.21	0.62	5.11	1.07	3.43	2.92	5.36	-1.73
IA	1.05	4.08	0.29	1.13	3.21	4.39	1.18	0.98	4.33	2.31	4.42	3.21	4.39	-0.58
KS	1.41	4.01	0.05	0.42	3.66	4.38	0.89	1.38	4.17	2.19	3.56	3.66	4.38	-1.17
KY	2.40	4.19	0.66	1.51	5.01	4.36	1.29	2.41	4.21	2.83	3.43	5.01	4.36	-1.06
LA	1.63	5.13	0.77	2.20	4.15	5.41	1.43	1.66	5.19	2.42	4.45	4.15	5.41	-1.07
ME	2.16	4.28	2.01	2.95	4.70	4.51	1.98	2.16	4.37	3.19	4.09	4.70	4.51	-0.59
MD	1.54	4.88	1.70	3.36	3.92	5.07	1.91	1.47	4.94	2.68	4.84	3.92	5.07	-0.59
MA	3.21	6.07	2.74	4.45	6.07	6.39	2.27	3.29	6.12	3.79	5.34	6.07	6.39	-0.60
MI	1.29	5.95	0.52	2.25	3.77	6.34	1.29	1.28	6.17	2.51	6.11	3.77	6.34	-0.58
MN	1.62	5.86	1.10	3.08	4.05	6.18	1.58	1.61	5.97	2.39	5.14	4.05	6.18	-1.06
MS	0.80	3.03	0.10	0.41	3.00	3.24	1.04	0.81	3.14	2.17	3.25	3.00	3.24	-0.60
MO	0.33	3.76	0.45	1.55	2.52	4.02	1.34	0.34	3.95	1.75	4.25	2.52	4.02	-0.58
MT	2.33	1.46	1.82	1.37	4.85	1.53	1.83	2.36	1.47	3.39	1.41	4.85	1.53	-0.56
NE	1.01	6.13	0.13	1.50	3.53	6.51	1.04	1.04	6.16	1.07	3.71	3.53	6.51	-1.80
NV	0.93	2.71	0.10	0.36	3.27	2.90	0.95	1.00	2.85	2.36	2.93	3.27	2.90	-0.52
NH	1.92	1.39	2.18	1.19	4.28	1.47	2.07	1.91	1.42	3.04	1.37	4.28	1.47	-0.60
NJ	1.59	3.57	2.02	2.73	3.98	3.79	2.07	1.59	3.66	2.79	3.56	3.98	3.79	-0.60
NM	1.56	4.79	1.04	2.47	4.12	5.06	1.53	1.67	4.90	2.84	4.77	4.12	5.06	-0.56
NY	1.36	2.84	1.99	2.24	3.59	3.02	2.07	1.29	2.92	2.57	2.92	3.59	3.02	-0.58
NC	2.17	4.87	0.72	1.88	4.78	5.11	1.34	2.21	4.87	2.20	3.54	4.78	5.11	-1.37
ND	1.80	4.86	1.12	2.53	4.21	5.18	1.58	1.74	5.03	2.89	4.84	4.21	5.18	-0.59
OH	2.65	3.18	0.26	0.70	5.22	3.46	1.01	2.65	3.35	3.54	3.07	5.22	3.46	-0.58
OK	1.57	4.11	0.13	0.63	3.93	4.52	0.98	1.52	4.36	2.74	4.28	3.93	4.52	-0.58
OR	1.32	2.21	1.76	1.64	3.72	2.32	1.91	1.38	2.25	2.65	2.24	3.72	2.32	-0.57
PA	2.10	3.80	1.16	2.03	4.48	3.99	1.58	2.01	3.87	3.10	3.67	4.48	3.99	-0.59
RI	1.45	4.69	2.08	3.78	3.89	4.93	2.17	1.46	4.75	2.68	4.67	3.89	4.93	-0.59
SC	1.85	5.85	0.94	2.77	4.29	6.14	1.48	1.70	5.82	1.23	3.27	4.29	6.14	-1.81
SD	2.40	3.92	0.99	1.85	4.90	4.12	1.48	2.37	3.99	3.34	3.70	4.90	4.12	-0.59
TN	1.32	3.82	0.43	1.22	3.56	4.04	1.25	1.27	3.91	2.24	3.49	3.56	4.04	-1.06
TX	1.31	3.45	0.11	0.50	3.59	3.61	0.98	1.27	3.52	2.55	3.53	3.59	3.61	-0.57
UT	2.72	9.17	0.90	4.01	6.06	9.56	1.38	3.02	9.11	2.31	6.19	6.06	9.56	-1.33
VT	2.61	5.25	2.69	3.95	5.30	5.41	2.27	2.62	5.25	3.47	4.75	5.30	5.41	-0.60
VA	1.27	3.33	1.51	2.30	3.62	3.46	1.83	1.30	3.37	2.57	3.36	3.62	3.46	-0.59
WA	1.63	5.25	2.16	4.20	4.20	5.46	2.17	1.78	5.34	2.93	5.17	4.20	5.46	-0.57
WV	1.22	7.48	0.15	2.01	3.90	8.02	1.04	1.26	7.80	2.45	7.70	3.90	8.02	-0.59
WI	1.86	5.43	0.78	2.23	4.35	5.69	1.38	1.85	5.55	2.83	5.11	4.35	5.69	-0.77
WY	1.03	6.68	1.05	3.97	3.55	7.03	1.64	1.12	6.83	2.05	6.14	3.55	7.03	-1.05

Table 7: **Wealth Effect Regressions in Data Simulated to Match the Mean Housing Wealth Growth.** This table displays the results of regressions estimated on 500 panels of simulated data. For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the mean of housing wealth growth in each state. Panel A of Table 6 presents details of this calibration. The dependent variable of the regressions under the column labeled 'Dep. var. Δw^H' is the log-growth of housing wealth (Δw^H). The dependent variable of the regressions under the column labeled 'Dep. var. Δc' is the log-growth of non-housing consumption. The independent variables are Δw^H and the log-growth of non-housing capital (Δk). All the variables are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. The results in Panels A, B, C, and D are based on different levels of noise-to-signal ratio. That is, in Panel A (B;C;D), for each state in each simulation, the variance of the measurement error is equal to 0% (50%; 100%; 150%) of the variance of each of the error-free simulated variables – Δc, Δw^H and Δk – obtained in that simulation. All panels have state-level fixed effects. β_{w^H}, β_k and α are the average across all simulated panels of the estimated coefficients on Δw^H, Δk and state-level fixed effects. The value in parentheses below the coefficient is the average T-statistic. The last row of each panel contains the average of the overall R^2 (in %) of the simulated regressions.

	Dep var Δw^H	Dep var Δc (1)	(2)	(3)
	Panel A: No measurement errors			
β_{w^H}		1.3842		0.0120
		(55.10)		(6.15)
β_k	0.4547		0.9606	0.9541
	(18.87)		(759.89)	(761.88)
α	0.0057	-0.0018	-0.0002	-0.0003
	(0.52)	(-0.24)	(-0.83)	(-0.91)
R^2	60.96	60.94	99.74	99.75
	Panel B: 50% noise-to-signal ratio			
β_{w^H}		0.9204		0.4370
		(24.27)		(13.61)
β_k	0.3044		0.6389	0.5043
	(8.19)		(33.64)	(27.74)
α	0.0081	0.0042	0.0053	0.0017
	(0.74)	(0.34)	(0.67)	(0.20)
R^2	28.01	27.92	44.28	48.71
	Panel C: 100% noise-to-signal ratio			
β_{w^H}		0.6901		0.4145
		(16.71)		(10.97)
β_k	0.2286		0.4783	0.3830
	(5.64)		(21.69)	(17.97)
α	0.0093	0.0072	0.0080	0.0042
	(0.78)	(0.57)	(0.76)	(0.39)
R^2	16.07	15.98	24.86	29.71
	Panel D: 150% noise-to-signal ratio			
β_{w^H}		0.5521		0.3712
		(12.91)		(9.20)
β_k	0.1831		0.3819	0.3137
	(4.36)		(16.37)	(13.80)
α	0.0101	0.0090	0.0097	0.0059
	(0.76)	(0.66)	(0.78)	(0.48)
R^2	10.44	10.36	15.89	20.12

Table 8: **Wealth Effect Regressions in Data Simulated to Match the Volatility of Housing Wealth Growth.** This table displays the results of regressions estimated on 500 panels of simulated data. For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the volatility of housing wealth growth in each state. Panel B of Table 6 presents details of this calibration. The dependent variable of the regressions under the column labeled 'Dep. var. Δw^H' is the log-growth of housing wealth (Δw^H). The dependent variable of the regressions under the column labeled 'Dep. var. Δc' is the log-growth of non-housing consumption. The independent variables are Δw^H and the log-growth of non-housing capital (Δk). All the variables are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. The results in Panels A, B, C, and D are based on different levels of noise-to-signal ratio. That is, in Panel A (B;C;D), for each state in each simulation, the variance of the measurement error is equal to 0% (50%; 100%; 150%) of the variance of each of the error-free simulated variables – Δc, Δw^H and Δk – obtained in that simulation. All panels have state-level fixed effects. β_{w^H}, β_k and α are the average across all simulated panels of the estimated coefficients on Δw^H, Δk and state-level fixed effects. The value in parentheses below the coefficient is the average T-statistic. The last row of each panel contains the average of the overall R^2 (in %) of the simulated regressions.

	Dep var Δw^H	Dep var Δc (1)	(2)	(3)
	Panel A: No measurement errors			
β_{w^H}		1.0512		0.1104
		(211.58)		(95.20)
β_k	0.8858		0.9758	0.8759
	(182.96)		(822.45)	(813.66)
α	0.0124	-0.0123	-0.0002	-0.0016
	(3.96)	(-4.03)	(-1.24)	(-7.86)
R^2	94.04	94.61	99.78	99.82
	Panel B: 50% noise-to-signal ratio			
β_{w^H}		0.6996		0.4078
		(32.49)		(20.87)
β_k	0.5924		0.6490	0.4074
	(27.62)		(33.66)	(22.91)
α	0.0173	-0.0028	0.0053	-0.0018
	(1.94)	(-0.35)	(0.67)	(-0.24)
R^2	41.94	42.06	44.29	52.51
	Panel C: 100% noise-to-signal ratio			
β_{w^H}		0.5246		0.3461
		(21.18)		(14.87)
β_k	0.4449		0.4859	0.3320
	(18.03)		(21.70)	(15.68)
α	0.0197	0.0020	0.0080	0.0012
	(1.75)	(0.16)	(0.75)	(0.11)
R^2	23.68	23.68	24.86	32.72
	Panel D: 150% noise-to-signal ratio			
β_{w^H}		0.4196		0.2983
		(16.06)		(11.93)
β_k	0.3563		0.3880	0.2818
	(13.69)		(16.37)	(12.39)
α	0.0212	0.0048	0.0097	0.0033
	(1.62)	(0.36)	(0.77)	(0.27)
R^2	15.22	15.18	15.89	22.41

Table 9: **Wealth Effect Regressions in Data Simulated to Match the Mean Housing Wealth Growth and with Errors in Independent Variables.** This table displays the results of regressions estimated on 500 panels of simulated data. For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the mean housing wealth growth in each state. Panel A of Table 6 presents details of this calibration. The dependent variable of the panels is the log-growth of non-housing consumption (Δc). The independent variables in these panels are the log-growth of housing wealth (Δw^H) and the log-growth of non-housing capital (Δk). The independent variables in the panels are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. Each model and panel displays results with different noise-to-signal ratio in Δw^H and Δk. Each model contains the results when the variance of the measurement error of Δw^H is equal to 5%, 10%, or 30% of the variance of the error-free Δw^H in that simulation. Panel A (B and C) contains the results when the variance of the measurement error of Δk is equal to 5% (10% and 30%) of the variance of the error-free series of Δk obtained in that simulation. All estimated models have state-level fixed effects. β_{w^H}, β_k and α are the average across all simulated panels of the estimated coefficients on Δw^H, Δk and state-level fixed effects. The value in parentheses below the coefficient is the average T-statisic. The last row of each panel contains the average of the overall R^2 (in %) of the simulated regressions.

	Noise-to-signal ratio in Δw^H								
	5%			10%			30%		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Panel A: Noise-to-signal ratio in Δk equals 5%								
β_{w^H}	1.2576		0.1513	1.0640		0.1035	0.9222		0.0790
	(47.40)		(16.74)	(38.71)		(12.17)	(33.61)		(9.87)
β_k		0.9151	0.8466		0.9151	0.8687		0.9151	0.8799
		(164.86)	(158.62)		(164.86)	(160.65)		(164.86)	(161.68)
α	-0.0002	0.0006	-0.0004	0.0023	0.0006	-0.0001	0.0041	0.0006	0.0001
	(-0.10)	(0.29)	(-0.18)	(0.16)	(0.29)	(-0.05)	(0.38)	(0.29)	(0.03)
R^2	55.84	95.02	95.33	47.85	95.02	95.24	41.88	95.02	95.19
	Panel B: Noise-to-signal ratio in Δk equals 10%								
β_{w^H}	1.3177		0.2961	1.2576		0.2640	1.0640		0.1851
	(50.77)		(24.55)	(47.40)		(22.07)	(38.71)		(16.27)
β_k		0.8736	0.7462		0.8736	0.7604		0.8736	0.7949
		(118.04)	(109.07)		(118.04)	(110.11)		(118.04)	(112.60)
α	-0.0010	0.0013	-0.0007	-0.0002	0.0013	-0.0004	0.0023	0.0013	0.0001
	(-0.17)	(0.48)	(-0.20)	(-0.10)	(0.48)	(-0.15)	(0.16)	(0.48)	(0.01)
R^2	58.28	90.72	91.85	55.84	90.72	91.75	47.85	90.72	91.47
	Panel C: Noise-to-signal ratio in Δk equals 30%								
β_{w^H}	1.3177		0.6015	1.2576		0.5487	1.0640		0.4071
	(50.77)		(34.80)	(47.40)		(31.68)	(38.71)		(24.09)
β_k		0.7395	0.5233		0.7395	0.5426		0.7395	0.5942
		(68.74)	(57.70)		(68.74)	(58.78)		(68.74)	(61.57)
α	-0.0010	0.0035	-0.0009	-0.0002	0.0035	-0.0005	0.0023	0.0035	0.0005
	(-0.17)	(0.86)	(-0.18)	(-0.10)	(0.86)	(-0.12)	(0.16)	(0.86)	(0.09)
R^2	58.28	76.81	82.71	55.84	76.81	82.26	47.85	76.81	80.98

Table 10: **Wealth Effect Regressions in Data Simulated to Match the Volatility of Housing Wealth Growth and with Errors in Independent Variables.** This table displays the results of regressions estimated on 500 panels of simulated data. For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the volatility of housing wealth growth in each state. Panel B of Table 6 presents details of this calibration. The dependent variable of the panels is the log-growth of non-housing consumption (Δc). The independent variables in these panels are the log-growth of housing wealth (Δw^H) and the log-growth of non-housing capital (Δk). The independent variables in the panels are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. Each model and panel displays results with different noise-to-signal ratio in Δw^H and Δk. Each model contains the results when the variance of the measurement error of Δw^H is equal to 5%, 10%, or 30% of the variance of the error-free Δw^H in that simulation. Panel A (B and C) contains the results when the variance of the measurement error of Δk is equal to 5% (10% and 30%) of the variance of the error-free series of Δk obtained in that simulation. All estimated models have state-level fixed effects. β_{w^H}, β_k and α are the average across all simulated panels of the estimated coefficients on Δw^H, Δk and state-level fixed effects. The value in parentheses below the coefficient is the average T-statisic. The last row of each panel contains the average of the overall R^2 (in %) of the simulated regressions.

	Noise-to-Signal ratio in Δw^H								
	5%			10%			30%		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Panel A: Noise-to-signal ratio in Δk equals 5%								
β_{w^H}	1.0010		0.3834	0.9555		0.2807	0.8085		0.1365
	(124.62)		(79.13)	(98.79)		(54.65)	(63.19)		(26.38)
β_k		0.9295	0.6033		0.9295	0.6912		0.9295	0.8139
		(165.51)	(134.27)		(165.51)	(143.44)		(165.51)	(155.23)
α	-0.0110	0.0006	-0.0045	-0.0098	0.0006	-0.0031	-0.0058	0.0006	-0.0012
	(-2.81)	(0.30)	(-2.42)	(-2.24)	(0.30)	(-1.72)	(-1.09)	(0.30)	(-0.69)
R^2	90.11	95.06	96.76	86.01	95.06	96.32	72.78	95.06	95.68
	Panel B: Noise-to-signal ratio in Δk equals 10%								
β_{w^H}	1.0010		0.5421	0.9555		0.4241	0.8085		0.2276
	(124.62)		(93.26)	(98.79)		(66.65)	(63.19)		(33.81)
β_k		0.8874	0.4478		0.8874	0.5439		0.8874	0.7035
		(118.30)	(84.45)		(118.30)	(93.01)		(118.30)	(105.55)
α	-0.0110	0.0013	-0.0062	-0.0098	0.0013	-0.0046	-0.0058	0.0013	-0.0019
	(-2.81)	(0.49)	(-2.57)	(-2.24)	(0.49)	(-1.89)	(-1.09)	(0.49)	(-0.77)
R^2	90.11	90.76	95.23	86.01	90.76	94.27	72.78	90.76	92.66
	Panel C: Noise-to-signal ratio in Δk equals 30%								
β_{w^H}	1.0010		0.7726	0.9555		0.6671	0.8085		0.4316
	(124.62)		(110.36)	(98.79)		(83.03)	(63.19)		(46.33)
β_k		0.7513	0.2225		0.7513	0.2949		0.7513	0.4562
		(68.80)	(37.46)		(68.80)	(43.20)		(68.80)	(53.70)
α	-0.0110	0.0035	-0.0086	-0.0098	0.0035	-0.0069	-0.0058	0.0035	-0.0033
	(-2.81)	(0.86)	(-2.72)	(-2.24)	(0.86)	(-2.09)	(-1.09)	(0.86)	(-0.92)
R^2	90.11	76.85	92.81	86.01	76.85	90.65	72.78	76.85	85.82

Figure 1: **Ilustration of the model.** This figure presents the model solution using the parameter values in Table 5 as well as $\alpha = 4.05\%$, $\sigma = 6.18\%$, and $\omega_0 = 1.58\%$. Panel A shows housing prices (P) and consumption to non-housing capital ratio (C/K) as function of the log of the ratio of housing to non-housing capital (ω). Panel B shows the log of housing prices (p) and of consumption (c) as functions of the log of non-housing capital (k).

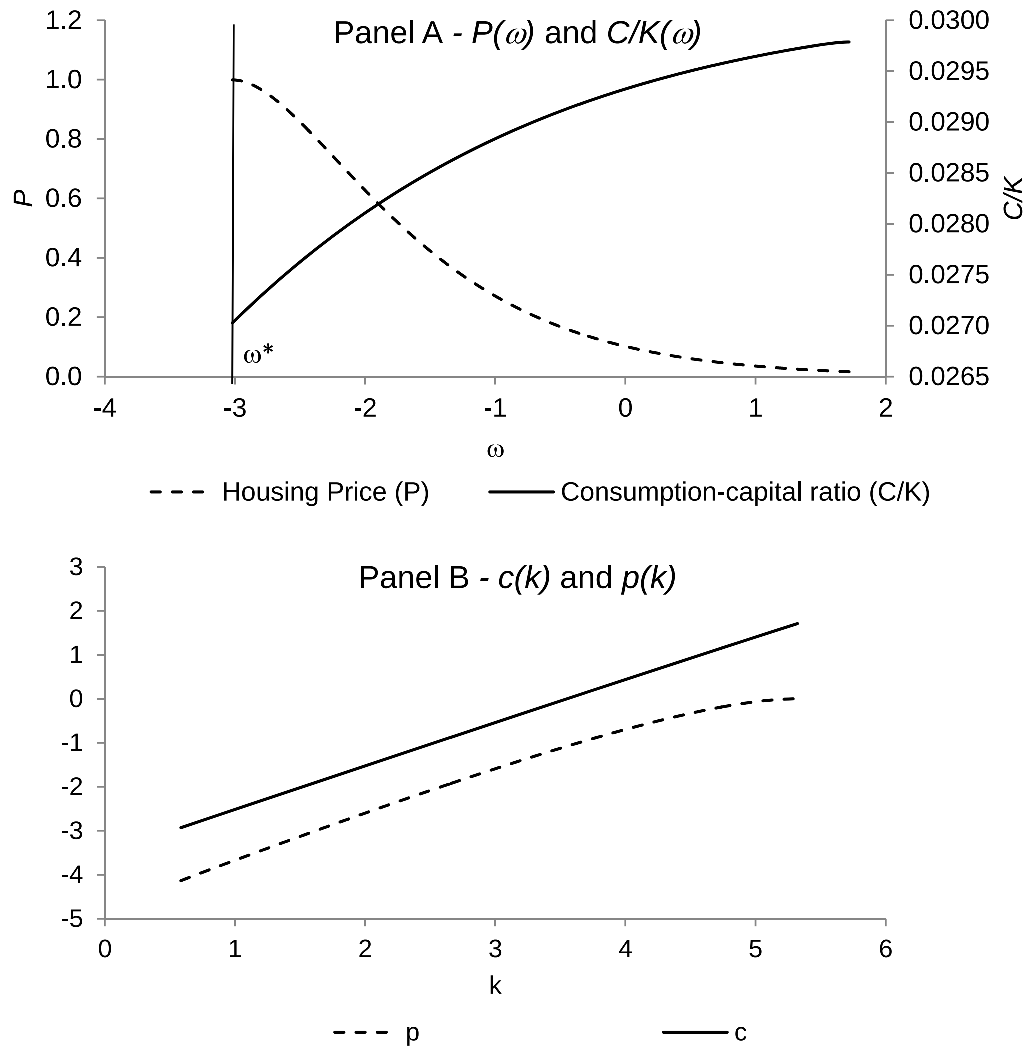
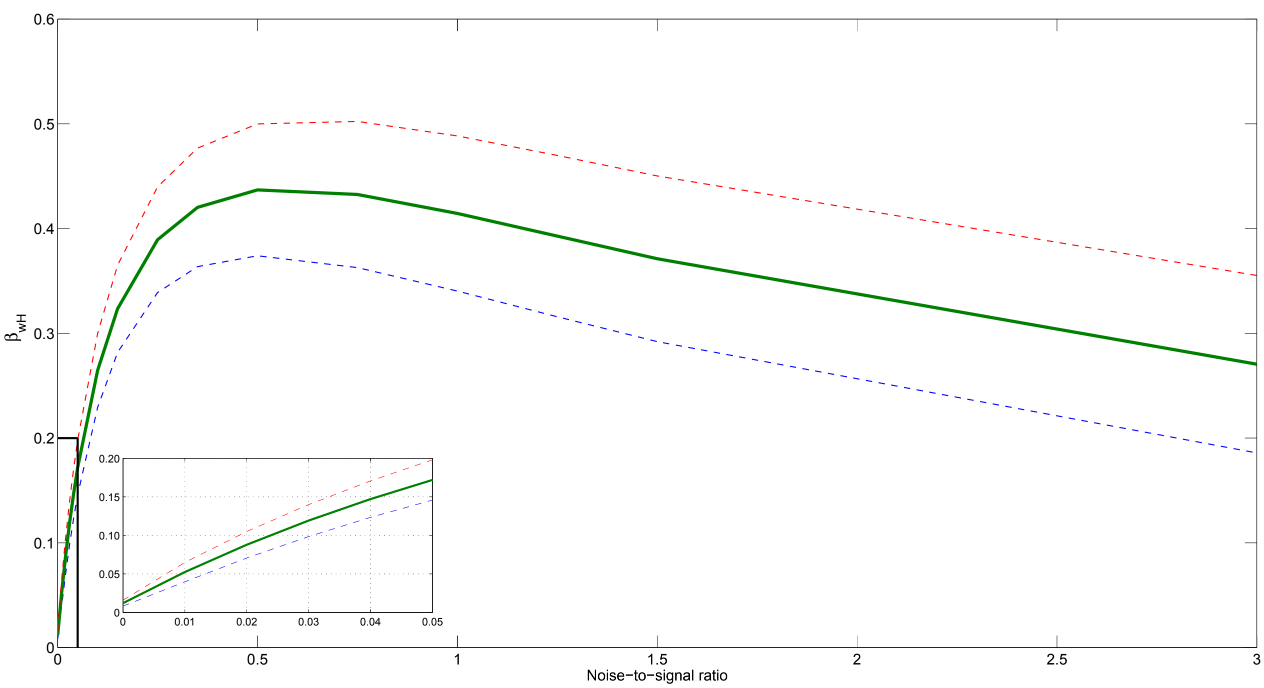


Figure 2: **Housing wealth effect as a function of errors in variables.** This figure plots the mean estimated housing wealth effect β_{w^H} in fixed-effect regressions across 500 panels of data simulated for each level of the noise-to-signal ratio in the dependent and independent variables. The dependent variable of the panels is the log-growth of non-housing consumption (Δc). The independent variables in these panels are the log-growth of housing wealth (Δw^H) and the log-growth of non-housing capital (Δk). For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the mean of housing wealth growth in each state. All the variables are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. 500 simulations are generated for each of the chosen levels of the noise-to-signal ratio between 1% and 300%. For example, for the case of a noise-to-signal ratio of 10%, for each state in each simulation, the variance of the measurement error is equal to 10% of the variance of each of the error-free simulated variables Δc, Δw^H and Δk obtained in that simulation. All panels have state-level fixed effects. The dotted lines indicate the 95% confidence interval bands for the parameter estimates. The inset figure magnifies the section of the graph between 0% and 5% noise-to-signal ratio.



Internet Appendix: Omitted Variable Bias and the Housing Wealth Effect

Narayan Bulusu Jefferson Duarte Carles Vergara-Alert*

August 2018

*Bulusu is with the Bank of Canada, Duarte with the Jesse H. Jones Graduate School of Business, Rice University and Vergara-Alert is with IESE Business School, University of Navarra. E-mail addresses: nbulusu@bank-banque-canada.ca (Bulusu), jefferson.duarte@rice.edu (Duarte), CVergara@iese.edu (Vergara-Alert). Carles Vergara-Alert acknowledges the financial support of the Public-Private Sector Research Center at IESE, the Ministry of Economy of Spain (ref. ECO2015-63711-P) and the Government of Catalonia (ref: 2014-SGR-1496). The views expressed in this paper are those of the authors. No responsibility for them should be attributed to the Bank of Canada.

Appendix

A - Details of the model

Kogan (2001, 2004) models a two-sector economy, each with a specialized capital input required to produce the two types of consumption goods or services in the economy. Capital in sector H (the housing sector) can only produce housing services. Capital in sector K (the non-housing sector) can either be used to produce the consumption good, C, or converted into housing stock, H. Investment in the housing sector is irreversible; that is, houses cannot be liquidated and turned into the consumption good.

The stock of non-housing capital (K_t) follows the equation of motion:

$$dK_t = (\alpha K_t - C_t)dt + \sigma K_t dW_t - dI_t, \tag{1}$$

where α and σ are, respectively, the mean and volatility of shocks to growth in non-housing capital, and dW_t is an increment of a standard Brownian motion. dI_t is the investment in the housing sector at time t.

Identical, perfectly competitive firms own all of the capital in sector H used to produce the housing service XH_t for consumption, with X representing the productivity of the housing sector; firms rent out the houses that they own. Firms determine the level of investment at each t to solve the maximization problem

$$\max_{\{I\}_{0\leq t<\infty}} E_0 \left[\int_0^\infty \eta_{0t} S_t X H_t dt - \eta_{0t} dI_t \right], \tag{2}$$

where S_t is the rent for one unit of housing in units of the consumption good C at time t, and is η_{0t} is firms' the stochastic discount factor. The first term in the integral above is the present value of all the rents that firms receive from housing. The second term is the present value of all the investment in housing. Changes in the housing stock are given by

$$dH_t = -\delta H_t dt + dI_t, \tag{3}$$

where δ is the rate of depreciation.

Households maximize their expected lifetime utility:

$$\max_{\{C_t, I_t\}_{0\leq t<\infty}} E_0 \left[\int_0^\infty e^{-\rho t} U(C_t, XH_t) dt \right], \tag{4}$$

where ρ is the parameter that specifies household impatience. Households, whose coefficient of risk aversion is γ, have utility separable over the consumption good, C_t, and housing services, XH_t, given by[1]

$$U\left(C_t, XH_t\right) = \frac{1}{1-\gamma}\left(C_t\right)^{1-\gamma} + \frac{b}{1-\gamma}\left(XH_t\right)^{1-\gamma}, \gamma > 0, \gamma \neq 1, \tag{5}$$

where b can be interpreted as the parameter that captures the size of sector H as a fraction of the whole economy.

Households also have access to two long-term financial assets. The value of the first asset at time t is v_t and it follows the dynamic $dv_t = \alpha v_t dt + \sigma v_t dW_t$. The second asset is a claim on all housing sector cash flows; in other words, the second claim is equivalent to the stock in the housing sector firms. In addition, households have access to a short-term bond.

Kogan (2001) shows that an equilibrium exists in which the processes for K_t, H_t, C_t, and I_t are equivalent to the solution of a central planner problem that chooses C_t and I_t to solve the maximization in Equation 4, subject to Equations 1 and 3. In fact, the central planner's choice of the control variables depends only on the state variable $\omega_t = \ln(\Omega_t) = \ln(H_t/K_t)$. In equilibrium, the optimal consumption policy is given by the following equation:

$$\widetilde{c}(\omega_t) = \frac{C_t}{K_t} = \left(f(\omega_t) - \frac{1}{1-\gamma} f'(\omega_t)\right)^{-\frac{1}{\gamma}}, \tag{6}$$

where f is the function that satisfies the ordinary differential equation (ODE)

$$p_2 f''(\omega) + p_1 f'(\omega) + p_0 f(\omega) + \gamma\left(f(\omega) - \frac{1}{1-\gamma} f'(\omega)\right)^{1-\frac{1}{\gamma}} = -be^{(1-\gamma)\omega}, \tag{7}$$

subject to the boundary conditions

$$f'(\omega^*)\left(1+\Omega^*\right) = f(\omega^*)\Omega^*(1-\gamma) \tag{8}$$

$$f''(\omega^*)\left(1+\Omega^*\right) = f'(\omega^*)\left(1+(1-\gamma)\Omega^*\right) \tag{9}$$

$$\lim_{\omega\to\infty} f(\omega) = \left(\alpha\frac{\gamma-1}{\gamma} - \frac{\sigma^2}{2}(\gamma-1) + \frac{\rho}{\gamma}\right)^{-\gamma}, \tag{10}$$

[1] Kogan (2001) also considers the case $\gamma = 1$; the qualitative relationships between the variables that we investigate in our study – consumption, investment, and prices – do not change if we use $\gamma = 1$.

and p_0, p_1, p_2 are constants with the following values:

$$p_0 = (1-\gamma)\alpha - \gamma(1-\gamma)\frac{\sigma^2}{2} - \rho \tag{11}$$

$$p_1 = -\alpha - \delta + (2\gamma - 1)\frac{\sigma^2}{2} \tag{12}$$

$$p_2 = \frac{\sigma^2}{2}. \tag{13}$$

The optimal housing investment policy is such that investment in housing only happens if ω is equal to an endogenously determined threshold, ω^*. Formally, the agent chooses $I_t = 0$ at t when $\omega_t > \omega^*$ and $I_t > 0$ when $\omega_t = \omega^*$. The variable ω follows the process

$$\begin{aligned} d\omega_t &= \mu_\omega(\omega_t)dt - \sigma dW_t + dL_t \\ \mu_\omega(\omega_t) &= -\alpha - \delta + \widetilde{c}_t(\omega_t) + \frac{\sigma^2}{2} \end{aligned}$$

where dL_t is zero when $\omega_t > \omega^*$ and is larger than zero when $\omega_t = \omega^*$. Consequently, dL_t is different from zero only when investment in the housing sector occurs. Specifically, $dL_t = (1 + \Omega^*)H_t^{-1}dI_t$ and ω is a process with a reflexive boundary at ω^*.

The market value of one unit of housing is given by

$$P(\omega_t) = \frac{f'(\omega)\Omega^{-1}}{(1-\gamma)\, f(\omega) - f'(\omega)}, \tag{14}$$

which is bounded by the replacement cost. This market value is equal to the housing Tobin's q, since the replacement cost is assumed to be equal to one.

We use Equations 6 and 14 to plot the consumption-to-capital ratio (C/K) and housing price (P) as a function of ω in Panel A of Figure 1 in the paper. For a fixed value of the housing stock, ω is a linear transformation of $\ln K$ (k), and we can rewrite Equations 6 and 14 to make C/K and P functions of k. In Panel B of Figure 1, we set H arbitrarily equal to 10, and plot $\ln P$ (p) and $\ln C$ (c) as functions of k using the parameters α and σ used to calibrate the model to Minnesota. (See Appendix C for details about this calibration.)

B - Simulating the model

We simulate the time series of housing price appreciation, consumption growth, and non-housing capital for each geographical area i following Kogan's model. The model parameters are those in Table 5 of the paper along with $\alpha_i, \sigma_i, \omega_{0,i}$ and Σ (the correlation matrix of shocks in non-housing capital across states). We choose the parameters based on the calibration procedure described in Appendix C. For a given value of the model parameters, we first solve the ODE in Appendix A to obtain the functions $f(\omega), \widetilde{c}(\omega_t), q(\omega_t)$ and ω^* for each i. We then simulate the time series of ω using the following algorithm:

1. For a given $\omega_{0,i}$, obtain the values of $\widetilde{c}(\omega_{0,i})$, and $q(\omega_{0,i})$.

2. Generate a random shock to the growth rate of non-housing capital $\Delta W_{\Delta t,i} \sim \mathcal{N}\left(\mathbf{0}, \sigma^2 \Delta t\right)$. The correlation of these random shocks across states is Σ. We divide the time interval between successive observations into 1000 intervals, i.e., we set $\Delta t = 1/1000$ in all our simulations.

3. Find $\omega_{\Delta t,i}$ with the discrete approximation $\omega_{\Delta t,i} = \omega_{0,i} + \mu_\omega(\omega_{0,i})\Delta t - \sigma_i \Delta W_{\Delta t,i}$

4. If $\omega_{\Delta t,i} > \omega_i^*$ proceed to next point; otherwise, make $\Delta L_{0,i} = \omega_i^* - \omega_{\Delta t,i}$, and $\omega_{\Delta t,i} = \omega_{\Delta t,i} + \Delta L_{0,i}$

5. Calculate $\Delta I_{0,i}$ as $(1 + \Omega_i^*)^{-1} H_{t,i} \Delta L_{0,i}$, $\Delta H_{\Delta t,i}$ and $\Delta K_{\Delta t,i}$ with the Euler discrete approximation of Equations 3 and 1. Without loss of generality, we set $K_{0,i}$ equal to one.

6. Repeat Step 1 with $\omega_{\Delta t,i}$ instead of $\omega_{0,i}$ until a time series with length $T = 30$ for the variables of interest is obtained.

C - Model calibration

We choose the parameters α_i and σ_i to enable the mean and volatility of consumption growth in the simulations to match the data from geographical area i. We choose the parameter $\omega_{0,i}$ to match either the mean, or the volatility of, housing price appreciation shown in Table 2 of paper. We choose the correlation matrix Σ to match the correlations of consumption growth in Table 3.

The starting point of our calibration is the observation that although $\widetilde{c}(\omega_{t,i})$ is a non-linear function (see Figure 1 in the paper), the variation in $\widetilde{c}(\omega_{t,i})$ is small and can be approximated by a constant. In fact, $\widetilde{c}(\omega_{t,i})$ is close to:

$$\widetilde{c}_i = \lim_{\omega_{t,i}\to\infty} \widetilde{c}(\omega_{t,i}) = \frac{\gamma-1}{\gamma}\alpha_i - \sigma_i^2\frac{\gamma-1}{2} + \frac{\rho}{\gamma} \tag{15}$$

As a result, in our calibration, we choose the parameters $\alpha_{i,}$ σ_i and Σ in which the amount of housing is much larger than the amount of non-housing capital ($\omega_{t,i} \to \infty$). In this economy, the investment in housing is zero, and the log of non-housing capital follows an arithmetic Brownian motion:

$$dk_{t,i} = \left(\alpha_i - \widetilde{c}_i - \frac{1}{2}\sigma_i^2\right) dt + \sigma_i dW_{t,i}$$

Because the level of consumption is $C_{t,i} = \widetilde{c}_i K_{t,i}$, the log-consumption process has the same drift and volatility as $k_{t,i}$. We therefore set σ_i equal to the estimated volatility of consumption growth in Table 2 for geographical area i. We set the correlation matrix Σ equal to the matrix in Table 3. We use the parameter α_i to solve the following equation:

$$\left(\alpha_i - \widetilde{c}_i - \frac{1}{2}\sigma_i^2\right) = \bar{c}_i$$

where $\bar{c}_i$ is the mean consumption growth in Table 2 for geographical area i.

Once, the parameters α_i and σ_i are set, we solve the ODE in Appendix A and then simulate the model for each i as described in Appendix B using different starting values of $\omega_{0,i}$. We then search for the $\omega_{0,i}$ that minimizes the distance between simulated mean or volatility of housing price appreciation and that displayed in Table 2 for geographical area i.

D - Robustness of results using lagged variables as instruments

Under the permanent income hypothesis (PIH), current period consumption growth is driven by contemporaneous innovations in permanent income, and is independent of lagged changes in permanent income. Hence, one way to address the common factor hypothesis under the assumption that the PIH holds is to use lagged values of growth in consumption, income, housing, and non-housing wealth as instruments in an IV estimation of Equation 1 in the paper.

In this Appendix we show that our results are robust to using lagged variables as instruments. First, we verify that the results in Table 4 are robust to using the first four lags of the growth of consumption, income, tradeable, and housing wealth, as instruments.

The estimate of the wealth effect, β_{w^H}, reported in Appendix Table 1, is 11.17% for the full model, which is very similar to the corresponding value of 12.66% obtained in fixed-effects regressions reported in Table 4. Second, we verify that our simulation results are not changed with this IV approach. The results of the fixed-effects regressions using the first four lags of the growth of consumption, housing, and non-housing wealth as instruments are shown in Appendix Table 2. Comparing Appendix Table 2 with Table 7, we see no significant differences in the magnitude of β_{w^H} estimated with or without IVs.

References

Kogan, Leonid, 2001, An equilibrium model of irreversible investment, *Journal of Financial Economics* 62, 201–245.

———, 2004, Asset prices and real investment, *Journal of Financial Economics* 73, 411–431.

Appendix Table 1: **The Housing Wealth Effect in Historical Data Using Instrumental Variables Estimation.** This table presents the results of panel data regressions of annual aggregated non-housing log-consumption growth (Δc) on the growth of log-housing wealth (Δw^H) and log-income growth (Δy). State-level fixed effects are included in all models and one specification controls for the log of non-housing tradable wealth (Δw^{TR}). All independent variables are instrumented by the first four lags of all of Δw^H, Δw^{TR}, and Δy. β_{w^H} and β_y are the coefficients of the terms Δw^H and Δy, respectively. α is the average of the fixed effect. The value in parentheses below the coefficient is the T-statistic . Overall R^2 (in %) values are reported in the last row. The sample contains observations at annual frequency for the period 1976–2012.

	(1)	(2)	(3)	(4)
β_{w^H}	0.3521		0.1473	0.1117
	(9.24)		(3.44)	(2.44)
β_y		1.0368	0.8479	0.8752
		(12.45)	(8.59)	(8.62)
α	0.0116	-0.0001	0.0015	-0.0023
	(9.31)	(-0.05)	(0.93)	(-1.05)
Δw^{TR} control	No	No	No	Yes
R^2	0.0777	0.1509	0.1730	0.1510

Appendix Table 2: **Wealth Effect Regressions Using Instrumental Variables in Data Simulated to Match the Mean Housing Wealth Growth and with Errors in Independent Variables.** This table displays the results of regressions estimated on 500 panels of simulated data, where all independent variables are instrumented by the first four lags of Δw^H, Δk and Δc. For each state in each simulation, 30 years of data are generated using the calibrated theoretical model. The data are simulated with the theoretical model calibrated to match the mean housing wealth growth in each state. Panel A of Table 6 presents details of this calibration. The dependent variable of the panels is the log-growth of non-housing consumption (Δc). The independent variables in these panels are the log-growth of housing wealth (Δw^H) and the log-growth of non-housing capital (Δk). The independent variables in the panels are assumed to have mean-zero normally-distributed measurement error that are independent of each other and independent of the shocks to non-housing capital. Each model and panel displays results with different noise-to-signal ratio in Δw^H and Δk. Each model contains the results when the variance of the measurement error of Δw^H is equal to 5%, 10%, or 30% of the variance of the error-free Δw^H in that simulation. Panel A (B and C) contains the results when the variance of the measurement error of Δk is equal to 5% (10% and 30%) of the variance of the error-free series of Δk obtained in that simulation. All estimated models have state-level fixed effects. β_{w^H} , β_k and α are the average across all simulated panels of the estimated coefficients on Δw^H, Δk and state-level fixed effects. The value in parentheses below the coefficient is the average T-statisic. The last row of each panel contains the average of the overall R^2 (in %) of the simulated regressions.

	Noise-to-Signal ratio in Δw^H								
	5%			10%			30%		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
	Panel A: Noise-to-signal ratio in Δk equals 5%								
β_{w^H}	1.37		0.17	1.30		0.14	1.07		0.10
	(44.42)		(9.75)	(41.39)		(9.08)	(33.62)		(7.35)
β_k		0.91	0.84		0.91	0.85		0.91	0.87
		(152.75)	(95.87)		(152.75)	(99.61)		(152.75)	(110.45)
α	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(-5.03)	(3.63)	(-3.37)	(-2.42)	(3.63)	(-2.63)	(5.14)	(3.63)	(-0.76)
R^2	0.58	0.95	0.95	0.55	0.95	0.95	0.45	0.95	0.95
	Panel B: Noise-to-signal ratio in Δk equals 10%								
β_{w^H}	1.37		0.29	1.30		0.26	1.07		0.18
	(44.42)		(13.41)	(41.39)		(12.49)	(33.62)		(10.13)
β_k		0.87	0.76		0.87	0.77		0.87	0.80
		(109.38)	(68.65)		(109.38)	(71.33)		(109.38)	(79.09)
α	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(-5.03)	(8.01)	(-3.41)	(-2.42)	(8.01)	(-2.38)	(5.14)	(8.01)	(0.27)
R^2	0.58	0.90	0.92	0.55	0.90	0.91	0.45	0.90	0.91
	Panel C: Noise-to-signal ratio in Δk equals 30%								
β_{w^H}	1.37		0.60	1.30		0.54	1.07		0.39
	(44.42)		(21.32)	(41.39)		(19.86)	(33.62)		(16.12)
β_k		0.74	0.54		0.74	0.56		0.74	0.61
		(63.69)	(39.97)		(63.69)	(41.53)		(63.69)	(46.05)
α	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	(-5.03)	(17.39)	(-3.85)	(-2.42)	(17.39)	(-2.29)	(5.14)	(17.39)	(1.86)
R^2	0.58	0.76	0.82	0.55	0.76	0.82	0.45	0.76	0.80