Consumption, House Prices and Collateral Constraints: A Structural Econometric Analysis

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Abstract

If borrowing capacity of indebted households is tied to the value of their home, house prices should enter a correctly specified aggregate Euler equation for consumption. I develop a simple two-agent, dynamic general equilibrium model in which home (collateral) values affect debt capacity and consumption possibilities for a fraction of the households. I then derive and estimate an aggregate consumption Euler equation, and estimate its structural parameters. The results provide robust support for housing prices as a driving force of consumption fluctuations. (JEL C2, E2, G1, R2)

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1. Introduction

The log-linear version of the Euler equation for consumption for a representative agent who can freely borrow and lend is:

$$c_t = E_t c_{t+1} - \sigma r_t \tag{1.1}$$

where c_t is the log-deviation of consumption at time t from its steady state value, $E_t c_{t+1}$ is its expected value conditional on information at time t, r_t is the change in the real short-term interest rate, and σ is the constant intertemporal elasticity of substitution for the class of preferences displaying constant relative risk aversion. This equation is the first-order approximation to the optimality condition for a lifetime maximization problem subject to a sequence of intertemporal budget constraints.[1]

At least since Campbell and Mankiw (1989) and Jappelli and Pagano (1989), various researchers have tried to estimate the above equation for consumption: (a) using aggregate time series data; (b) adding other explanatory variables besides expected consumption and interest rates on the right-hand side of the equation 1.1.[2]

Using aggregate time series data has the benefit of giving quantitative evidence on the aggregate time series properties of consumption, as well as the advantage of providing a direct test for models that rely on the assumption of a representative agent and complete markets. Adding other explanatory variables to the right-hand side of 1.1 can test whether all agents in the economy behave according to the life-cycle model and/or whether they face any additional constraint besides the intertemporal budget constraint. For instance, Campbell and Mankiw (1989) estimate a version of 1.1 adding income growth to the set of regressors. Their justification is that if some agents behave according to the simple rule $C_t = Y_t$, where Y_t is the current period income, then the coefficient on income should capture the fraction of so-called rule-of-thumb consumers.

The insight of the above mentioned studies is that aggregate time-series consumption is thought of as the result of the aggregate of two different types of consumers. However, describing rule-of-thumb consumers in the naive way $C_t = Y_t$ may omit important aspects of the reality. Consumers are actually inundated by

[1] See Carroll (2001) for a discussion. Carroll refers to equation 1.1 as the 'crude' approximation. A more precise second-order approximation would involve the expectation of the square of consumption growth, which is vanishingly small only when uncertainty is small or when σ is very large.

[2] Hall (1978) first tested the implications of the above model using time-series data. His emphasis was mostly on (a).

offers of car loans, credit cards, home equity loans, and so on. For example, as of 2003, homeowners had $315 billion in outstanding debt from home equity lines of credit, a 31 percent increase from the previous year. Falling interest rates and increasing house prices have played a part in this process, of course.

In addition, several commentators have expressed the consideration that rising house prices in the US and Europe have kept consumption growth high throughout the 1990's.[3] A high elasticity of consumption to house prices, which is a necessary condition for this hypothesis, is hard to reconcile with the traditional life-cycle model. Think about the simplest possible case, namely an exogenous increase in house prices. If the gains were equally distributed across all population, if all agents had the same propensity to consume and if all agents were to spend these gains on housing, total wealth less housing prices would remain unchanged, and so would the demand for non-housing consumption.[4] However, if liquidity constrained households value current consumption a lot (which might explain why they became liquidity constrained in the first place) they may be able to increase their borrowing and consumption more than proportionally when the value of their home rises, so that increases in house prices might have substantial first order effects on aggregate demand.

I embed these considerations into a simple model of aggregate consumption in an economy with collateral constraints tied to home values. My aim is to derive a properly specified, microfounded aggregate Euler equation for consumption, test it using aggregate time series data and identify its structural parameters. The main results are as follows: I find strong and compelling evidence for a direct effect from house prices to consumption. My estimates on US data for the period 1986-2002 suggest a point estimate of the long-run elasticity of consumption to house prices which is in the neighborhood of 0.2.

The emphasis on a full-blown general equilibrium model on the one hand and on structural estimation of its parameters on the other is the main difference between this paper and other studies that have tried to estimate the wealth effects from house price changes in various specifications of the consumption function.[5] Using a panel data sets of several industrialized countries, Case, Quigley and Shiller (2003) find elasticities

[3] See e.g. *The Economist*, "Home is where the wealth is.", September 1, 2001

[4] See Parker (2000) for a nice discussion of these issues.

[5] Some papers have introduced housing in dynamic general equilibrium models with a representative agent. See e.g. Davis and Heathcote (2003), who examine the business cycle properties of an RBC model with a construction sector, and Piazzesi, Schneider and Tulel (2003), who analyze the implication of housing and non-housing consumption for the prices of financial assets.

of house prices to consumption from 0.06 for a panel of US states to 0.14 using cross-country data. While the differences between my result and their result might be well driven by different specifications of the model as well as choice of the sample period, my emphasis is as much on the reduced form estimates as on the estimation of the structural parameters of the underlying model of consumption.

2. Do house price shocks affect consumption?

Before presenting the model, I present some non-structural evidence on the role of house prices in affecting consumption (and other macroeconomic variables).[6]

Figure 1 presents the impulse responses (with a 90% confidence interval) to a house price shock from a five-variable VAR[7] with Fed Funds rate (R), log real house prices (q), log consumption (ce), with log GDP (y), change in the log of GDP deflator (dp).[8] Here and throughout the paper, the variables are expressed in percentage terms and are all expressed in quarterly rates (including the interest rate).

The first ordering of the innovations that I consider is (R, q, ce, Y, dp). This way, house prices innovations are assumed to affect contemporaneously consumption (as well as income and inflation), but not vice-versa. The response of house prices to own innovations is persistent, and stays significant for about 3 years. The short-run elasticity of consumption is positive and significant, despite the increase in the real interest rate (from period 1 on) that might signal endogenous contractionary monetary policy. In particular, the short-run elasticity (in the first year) of total aggregate consumption to a real house price shock is around 20%, a large and sizeable number.

One problem with this evidence is that the direction of causality between house prices and other macro variables might also go in the opposite direction. In other words, house prices might go up in the first place

[6] For the period 1975-2002, the contemporaneous correlation between detrended (using a band-pass filter that isolates frequencies between 6 and 32 quarters) consumption and real house prices is 0.53. The maximum correlation between the two series occurs between c_t and q_{t+3}, and is 0.67. If anything, unconditional correlations suggest that house prices lag consumption.

[7] The VAR was estimated with a linear trend and constant. Two lags were chosen according to the Hannah-Quinn criterion.

[8] The sample period runs from 1975Q1 to 2002Q4. Later in the analysis, when I consider the structural estimation of the deep parameters of our consumption model, I shorten the time period of the estimation, since housing market liberalization might have changed some of the structural relationships. The data were taken from the St.Louis Fed FRED Database. The house price index is the Conventional Mortgage Home Price Index from Freddie MAC. The Fed Funds is the average value in the first month of each quarter. The VAR includes a constant and a time trend.

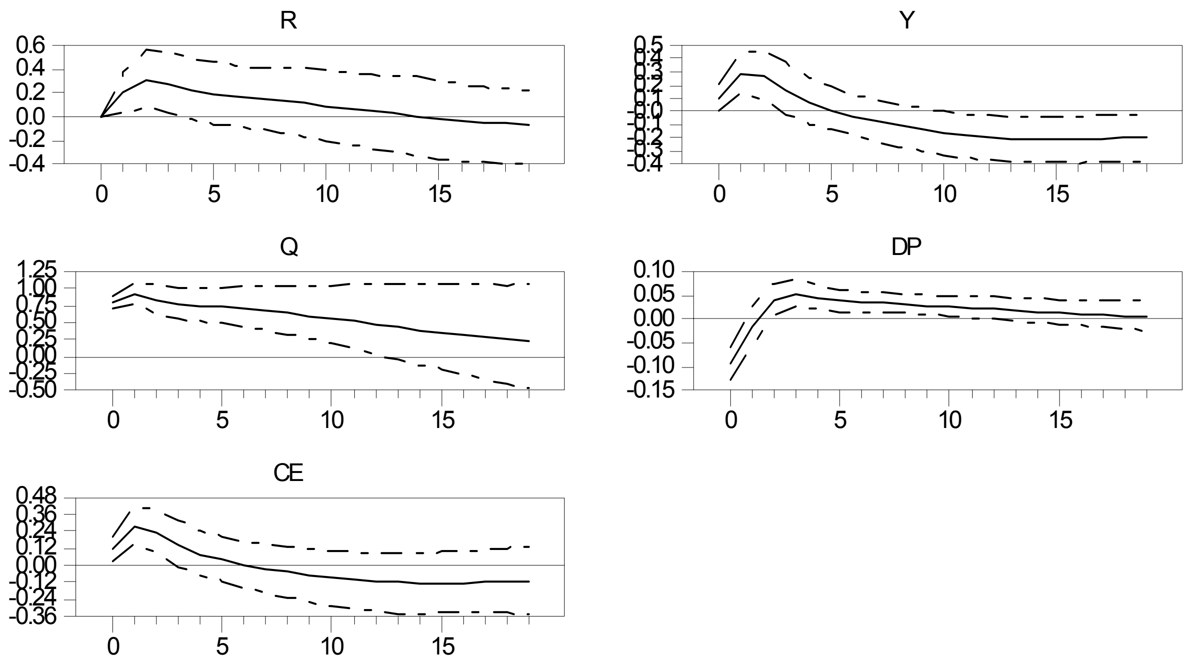

Figure 2.1: Impulse responses to a shock in real house prices, ordering (R, q, ce, Y, dp) .Ordinate: time horizon in quarters. Co-ordinate: percentage deviations from the baseline.

because of some endogenous reaction to increases in consumption, rather than vice versa. I run therefore another VAR in which house prices are ordered last. This time, an innovation in house prices can affect all macro variables only with some lag, whereas all other shocks can affect house prices contemporaneously. Even in this case, a house price innovation generates a positive and significant initial impact on consumption (despite the increase in the real rate), although consumption falls below the baseline two years after the initial shock.

As outlined in the introduction, these numbers are somehow at odds with the standard representative agent model. At most, reduced forms of such a model suggest that the marginal propensity to consume out of a permanent wealth shock should be a little number, something just over the real interest rate. Various explanations have been put forward to justify such a high elasticity. Unlike other financial assets, houses are in fact both an asset and a commodity, whose price reflects the stream of future utility services that houses will provide. In general, changes in house prices may have an ambiguous impact on aggregate consumption, since changes in house prices entail a distribution of resources between tenants and prospective new buyers,

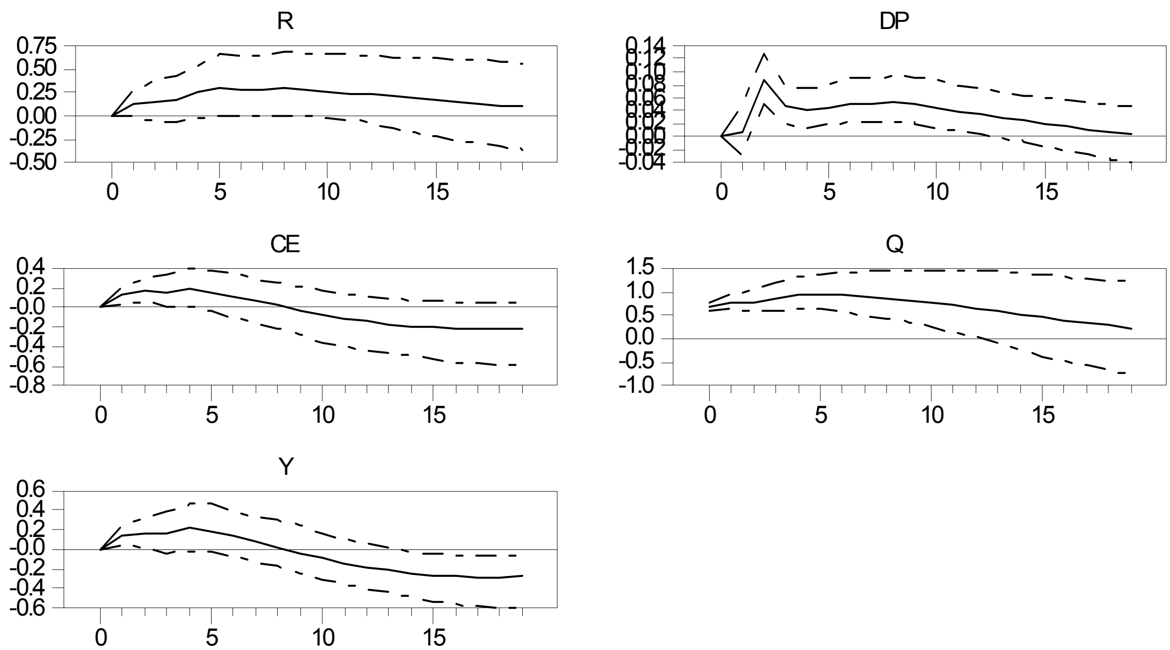

Figure 2.2: Impulse responses to a shock in real house prices, ordering (R, ce, Y, dp, q) .Ordinate: time horizon in quarters. Co-ordinate: percentage deviations from the baseline.

on the one hand, and current homeowners, on the other: among the homeowners, in addition, there might be different effects depending on the equity in the house that each homeowner has.

The above considerations make it clear that it is difficult to make precise inferences about the factors driving house price movements and their effects on consumption in absence of a full-blown general equilibrium model. The next section present such a model. In doing so, it also emphasizes an important channel that has been addressed by the recent literature, namely the "financial accelerator".[9] The basic idea goes as follows: changes in the market value of houses affect the borrowing capacity of indebted households and, therefore, the availability of loans. Therefore an increase in residential property prices permits households to borrow and to spend more. This way, changes in house prices can have sizeable effects on aggregate demand.

What I try and do in this paper is to estimate an aggregate consumption function that is consistent with the simplest possible model that formalizes these stories.

[9] See e.g. Bernanke and Gertler (1995), Iacoviello (2002) and Aoki, Proudman and Vlieghe (2001).

3. A model of consumption, house prices and liquidity constraints

I begin now by developing a model of the link between house prices, consumption and real economy.

Consider a perfect foresight, discrete time, infinite horizon, small open, endowment economy, populated by *constrained* and *unconstrained agents*, both infinitely lived and of measure, respectively, $1-\zeta$ and ζ.

Let me discuss in turn the working assumptions.

1. The term "unconstrained" households refers to the group which has a lower discount rate than the other. Although I define agents as *constrained* and *unconstrained* from the start, agents will be endogenously constrained and unconstrained, as will be explained below.

2. Both agents receive in each period some perishable endowment Y_t. They have preferences defined over consumption C and housing H.

3. Aggregate housing is normalized to some constant and is in constant supply in the aggregate. However, shifts in housing demand across the two groups will affect its equilibrium price and its allocation between unconstrained and constrained agents.

4. All agents can trade houses, the consumption good, and a riskless bond.

5. I assume the economy is open to the world. This guarantees that in equilibrium, even if total output is constant, changes in the net foreign asset position of the economy have direct effects on aggregate demand. If the net foreign asset position of the economy is denoted by F_t, the economy resource constraint will be:

$$C_t^c + C_t^u = Y_t^u + Y_t^c + F_t - R_{t-1}F_{t-1} \tag{3.1}$$

   where I assume that arbitrage implies that domestic and world interest rate are equal.

6. I also assume for tractability that only the unconstrained households can trade financial assets with the world. For standard moral hazard reasons (for instance foreign agents do not want to lend to constrained households), I exclude constrained agents from the world capital markets. This assumption simplifies the analysis, and has little impact on the results.

3.1. Unconstrained households

Unconstrained households maximize a standard lifetime utility function given by:

$$\max E_0 \sum\nolimits_{t=0}^{\infty} \beta^t \left(\frac{\left(C_t^u\right)^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} + j^u u\left(H_t^u\right) \right)$$

for all $t \geq 0$. E_0 denotes the expectation operator, β is the discount factor, σ is the intertemporal elasticity of substitution, j^u is the relative weight on housing services in the utility function. Households derive utility from consumption C_t^u and housing H_t^u (priced at Q_t), receive a random endowment Y_t^u, lend in real terms $-B_t^u$, receive back $R_{t-1}B_{t-1}^u$ where R_{t-1} is the real interest rate paid on loans made between $t-1$ and t.

Their flow of funds is:

$$C_t^u + Q_t\left(H_t^u - H_{t-1}^u\right) + R_{t-1}B_{t-1}^u + R_{t-1}^* F_{t-1} = B_t^u + F_t + Y_t^u$$

Solving this problem yields first order conditions for consumption and housing, once we acknowledge that housing is like a durable good that never depreciates:

$$\left(C_t^u\right)^{-1/\sigma} = \beta R_t E_t\left(\left(C_{t+1}^u\right)^{-1/\sigma}\right) \quad (3.2)$$

$$Q_t\left(C_t^u\right)^{-1/\sigma} = ju'\left(H_t^u\right) + E_t\left(\beta Q_{t+1}\left(C_{t+1}^u\right)^{-1/\sigma}\right) \quad (3.3)$$

Arbitrage implies that domestic interest rate equals the world interest rate ($R_t = R_t^*$ for all t). To ensure constant unconstrained household consumption in steady state, I assume that $\beta = 1/R^*$.[10]

3.2. Constrained households

The economy is also populated by a fraction ζ of constrained households, which assign a high weight to today's consumption and do not discount the future. In absence of a debt constraint, these households would accumulate infinite negative wealth. To make matters interesting, I assume there is a limit on their net obligations. The amount they can borrow cannot exceed a fraction $m \leq 1$ of the next period's expected value of real estate holdings discounted by the rate of interest. Their obligations B_t^c are thus bound by:

$$B_t^c \leq mE_t\left(Q_{t+1}\right)H_t^c/R_t \quad (3.4)$$

In other words, lenders (unconstrained households) impose a margin requirement on borrowers of $1-m$. I do not try to derive this constraint endogenously. However, this kind of borrowing limit could arise for

[10] This assumption is standard in small open economy models. See for instance Schmitt-Grohe and Uribe (2003).

instance due to liquidation costs, if – in case of default – legal and other cost amount to a fraction $1-m$ of the house value.[11]

These households solve the following problem:

$$\max \ln C_t^c + j^c u\left(H_t^c\right)$$

The assumption of log utility in consumption here simplifies tractability without affecting the derivations below. So long as these agents do not give weight to the future, these agents end up being constrained in equilibrium. The assumption of a more general functional form for housing demand leaves open the possibility that housing demand changes more or less strongly as house prices change. Later, I will describe how one can obtain an estimate of the own price elasticity of housing demand for these agents.

Constrained households are subject to the borrowing constraint above (equation 3.4) and to the following flow of funds:

$$C_t^c + Q_t\left(H_t^c - H_{t-1}^c\right) + R_{t-1}B_{t-1}^c = Y_t^c + B_t^c \tag{3.5}$$

Define Φ_t as the time t shadow value of the borrowing constraint. The first-order conditions for an optimum are the consumption Euler equation and real estate demand:

$$1/C_t^c = \Phi_t R_t \tag{3.6}$$

$$Q_t/C_t^c = ju'\left(H_t^c\right) + E_t\left(\Phi_t m Q_{t+1}\right) \tag{3.7}$$

The consumption Euler and the housing demand equations differ from the usual formulations in two respects. On the one hand, there is no discounting, hence the marginal utility of future consumption does not appear. On the other, the marginal utility of consumption today is affected by Φ_t, the Lagrange multiplier on the borrowing constraint. Φ_t equals the increase in lifetime utility that would stem from borrowing R_t dollars today and consuming the proceeds, and reducing consumption by an appropriate amount next period (which costs nothing in terms of utility).[12] One can notice that, since housing can be used as collateral, there is a distortion towards housing consumption in the model. Borrowing constraints affect the intertemporal allocation of resources as well as the within-period one, since real estate is both "good" and collateral.

[11] Borrowing constraints of this form are by now standard in the macro literature. See Kiyotaki and Moore (1997) and Miles (1992 and 1995), for instance.

[12] See Zeldes (1989) for an insightful discussion of the interpretation of the Lagrange multiplier in the consumption Euler equation.

Unconstrained households will borrow up to the limit and will be liquidity constrained in steady state (or in a neighborhood of it). In fact, the consumption Euler equation in the unconstrained households problem guarantees that, in steady-state, the gross real interest rate is $R = 1/\beta$, the unconstrained household time preference rate. Combining this result with the steady state constrained households Euler equation for consumption yields: $\Phi = \beta/C^{\frac{1}{\sigma}}$. Therefore, the borrowing constraint 3.4 will always hold with equality.[13]

3.3. Equilibrium

Two markets clear domestically: the real estate market and the domestic bond market. The respective market clearing conditions are given by (normalizing total housing supply to 1):

$$H_t^c + H_t^u = 1 \tag{3.8}$$

$$B_t^c + B_t^u = 0 \tag{3.9}$$

Without uncertainty, the model has a unique steady state equilibrium. This occurs because constrained agents always hit the borrowing constraint and borrow up to the limit, paying back in the steady state the interest rate on debt (see below) and rolling the equilibrium level of debt over forever. The equilibrium is an allocation $\{H_t^c, H_t^u, C_t^c, C_t^u, B_t^c, B_t^u, F_t\}_{t=0}^{\infty}$ together with the sequence of values $\{\Phi_t, Q_t\}_{t=0}^{\infty}$ satisfying equations 3.1 to 3.9 of the model and the relevant transversality conditions, given $\left\{H_{-1}^c, H_{-1}^u, B_{-1}^c, B_{-1}^u, F_{-1}\right\}$.[14]

Before I move to the derivation of an Euler equation for consumption, I briefly describe the steady state equilibrium of the model. In a steady state, for given stock of foreign bonds F,[15] consumption of the unconstrained agents (respectively: constrained agents) will be equal to income minus new loans (plus new borrowing) plus repayment of old loans (minus repayment of old loans). That is:

$$C^c = Y^c + B^c - RB^c = Y^c - \left(\frac{1-\beta}{\beta}\right) B^c \tag{3.10}$$

[13] In a neighborhood of the steady state, constrained households might want to hold of stock of assets as precautionary saving to insure again bad income shocks. Therefore, strictly speaking, if uncertainty is large there might be periods in which the borrowing constraint is not necessarily binding. If we confine ourselves to a perfect foresight equilibrium, we can neglect these issues.

[14] I am assuming here constant technology and constant world interest rate. The definition can be easily amended if we allow for technology and world interest rate to follow some exogenous stochastic process.

[15] This stock cannot be uniquely pinned down in the steady state given the assumption that $R^* = 1/\beta$.

assuming $R = 1/\beta$. For the lenders, using market clearing in the bond market:

$$C^u = Y^u + \left(\frac{1-\beta}{\beta}\right)(B^c - F) \tag{3.11}$$

In order to express B as a function of the model parameters, I first have to determine Q, the steady state housing price. To this end, I use the fact that the borrowing constraint binds in steady state, together with the assumption of market clearing in the housing market, to obtain steady state housing demands for respectively constrained and unconstrained:

$$\begin{aligned} \frac{Q}{C_c} &= \frac{j^c u'(H_c)}{1-m\beta} \\ \frac{Q}{C_u^\sigma} &= \frac{j^u u'(H_u)}{1-\beta} \end{aligned}$$

using the expressions for C^c and C^u above, as well as $H_c + H_u = 1$, one can solve the two equations above for H_c, H_u and Q. Once H_c and H_u are calculated, one can derive the consumption share of each group as fraction of total income. My empirical strategy will not be able to identify j^c, j^u, Y^c and Y^u. However, I will show how it is possible to recover an estimate of the consumption shares from the data. Moreover, I will also be able to estimate the slope of the housing demand curve for the constrained agents, as well as the implied loan-to-value ratio m.

One distinction worth highlighting is that the consumption *shares* of each group in total output (that I will call λ and $1-\lambda$ respectively below) will not necessarily correspond to the *mass* of each group in the economy. The consumption shares depend on total income, on the mass of each group, as well as on the steady state net repayment which flows each period from borrowers to lenders. What I will be able to identify in my empirical section is not the fraction of credit constrained consumers, but the fraction of consumption in total output of this group. This distinction is important because heterogeneity implies that income distribution matters in this economy.

4. Deriving an Euler equation for aggregate consumption

I consider the implications that this simple model has for the purpose of deriving a relationship between house prices and aggregate consumption. Intuitively, near the steady state increases in house prices, by affecting borrowers credit capacity, will relax their borrowing constraints, lead to higher borrowing and increase in their consumption. This happens because borrowers marginal propensity to consume is higher than lenders' (which justifies why they became borrowers in the first place). On the other hand, changes in consumption for the lenders will be only driven by unexpected movements in the interest rate, which is a sufficient statistic for predicting consumption changes.

From now on, I linearize the model around the deterministic steady state and let lower-case letters denote percentage deviations from the steady state. That is, for each variable X_t, I define $x_t \equiv (X_t - X)/X$

Aggregate consumption will be given by:

$$c_t = \lambda c_t^c + (1-\lambda) c_t^u$$

where λ and $1-\lambda$ are the consumption shares of each group.

For unconstrained households, the linearized Euler equation is standard, and is the one which has traditionally been tested in the literature beginning with Hall (1978). It states that, neglecting second order terms, consumption is negatively related to the long interest rate.

$$c_t^u = E_t c_{t+1}^u - \sigma r_t \tag{4.1}$$

For constrained households, the Euler equation holds with the addition of the multiplier on the borrowing the constraint:

$$c_t^c = -\phi_t - r_t \tag{4.2}$$

One can linearize the asset demand equation for borrowers/constrained agents to obtain:

$$q_t = m\beta E_t q_{t+1} - \theta(1-m\beta) h_t + m\beta\phi_t + c_t^c \tag{4.3}$$

where θ is the long-run inverse elasticity of housing demand for the borrowers. This expression states that for borrowers housing demand is related to the marginal utility of housing as well as to the tightness of the borrowing constraint.

Combining and rearranging 4.2 and 4.3 yields:

$$c_t^c = (1+\omega) q_t - \omega E_t q_{t+1} + \omega R_t + \theta h_t \tag{4.4}$$

where $1+\omega = \frac{1}{1-m\beta}$ is the inverse of the downpayment needed to purchase one unit of housing. This expression formalizes how, for borrowers, consumption is a positive function of house prices, with a coefficient that is equal to the inverse of the downpayment. Intuitively, by giving up one unit of consumption, a constrained agent can increase his housing demand by more than one, since the downpayment required to purchase one house is equal to $1/(1-m\beta)$.[16]

The key insight here is that in a fully specified general equilibrium model one can express the multiplier on the borrowers' constraint as a *specific* function of observable variables. To the extent that the tightness of the borrowing constraint is related to current and expected house prices and to housing demand, these variables should be able to explain current consumption.[17]

The next step is to aggregate 4.1 and 4.4 across agents to obtain an approximate consumption function for the aggregate economy. Summing across agents yields, after some algebra:

$$c_t = (1-\lambda) E_t c^u_{t+1} - (\sigma(1-\lambda) - \omega\lambda) r_t + \lambda((1+\omega) q_t - \omega E_t q_{t+1} + \theta h_t)$$

One problem with this expression is that the conditional expectation of unconstrained consumption, $E_t c^u_{t+1}$, cannot be observed. However, leading 4.2 one period ahead and solving for c^u_{t+1} gives:

$$E_t c^u_{t+1} = -\sigma E_t \sum_{i=0}^{\infty} r_{t+1+i} = -\sigma l_t$$

where l_t is the interest rate on a long term real rate (as opposed to r_t, which is the rate on one period bond).[18] Therefore, after some algebra, I can write the aggregate consumption Euler equation as:

$$c_t = -\psi_1 l_t + \psi_2 q_t - \psi_3 E_t q_{t+1} + \psi_4 r_t + \psi_5 h_t \tag{4.5}$$

In terms of the model structural parameters, the equation can be written as:

$$c_t = -\sigma(1-\lambda)(r_t + l_t) + \omega\lambda(q_t + r_t - E_t q_{t+1}) + \lambda q_t + \theta\lambda h_t \tag{4.6}$$

which explicitly takes into account the coefficient restrictions implied by the model. In particular, I can freely estimate only four coefficients, corresponding respectively to $\lambda, \sigma, \omega, \theta$.

[16] In the framework presented, I will not be able to identify β and m separately from the data. From now on, I aim at identifying $m\beta$ together.

[17] Studying the partial equilibrium problem of a liquidity constrained consumer, Pesaran and Smith (1995) propose to approximate the unknown Lagrange multipliers in the Euler equation by a general function of observable variables. My theory has the benefit of suggesting what these variables should be.

[18] More precisely, l_t should represent the *expected* interest rate at time t for time $t+1$ on a long term bond, that is l_{t+1}. In absence of a fully-fledged theory of the term structure, we prefer using l_t rather than constructing an estimate of l_{t+1}.

Since under rational expectations the error in the forecast of q_{t+1} is uncorrelated with information dated t and earlier, it follows from 4.6 that:

$$E_t \left\{ \left(c_t + \chi_1 \left(r_t + l_t \right) - \chi_2 \left(q_t + r_t - E_t q_{t+1} \right) - \chi_3 q_t - \chi_4 h_t \right) \mathbf{z}_t \right\} = 0 \tag{4.7}$$

where $\mathbf{z}_t$ is a vector of variables dated t and earlier (and, thus, orthogonal to the surprise in house prices in $t+1$). The above orthogonality condition forms the basis for estimating the model via generalized method of moments (GMM). Finally, the structural parameters can be recovered from the estimates of χ_1 to χ_4 in 4.7 using the following relationships: $\lambda = \chi_3$, $\sigma = \chi_1 / \left(1 - \chi_3\right)$, $\omega = \chi_2 / \chi_3$ and $\theta = \chi_4 / \chi_3$.

5. Testing the Euler equation

I use quarterly US data for the period 1986:1 to 2002:4. The choice of the sample period reflects the restructuring and the behavior of the housing finance system over the last decades. Before the mid-1980s, the housing finance system was dominated by regulated, highly specialized savings institutions. After the mid-1980s, the housing finance market has moved to a system where mortgage institutions are less regulated, the mortgage market is largely integrated into the broader capital market, and constraints on the *supply* of credit have largely disappeared. Of course, while the changes have largely affected the secondary mortgage market, the primary mortgage market still requires that homeowners pledge their house as collateral for the debt.[19]

I use the log change in real personal consumption expenditure for consumption.[20] The short-term real interest rate is constructed as the difference between the quarterly 3-month Treasury Bill and the quarter on quarter change in the GDP deflator.[21] The long real interest rate is the 10-Year Treasury Constant Maturity Rate minus change in log GDP deflator. The house price (logged and first differenced) is the Conventional Mortgage Home Price Index from Freddie MAC (deflated with the GDP deflator). Finally, I need to proxy for housing demand of the constrained agents: I assume that a valid measure of housing demand for these

[19] See McCarthy and Peach (2002).

[20] Unless otherwise stated, all the data were taken from the FRED database. I use total consumption expenditure (thus including durable goods) because my aim is to assess the sensitivity of total consumption to movements in house prices.

[21] I experimented using inflation in $t+1$ (and using the so constructed real interest rate measures as instruments from $t-2$ backwards). The results were very similar.

agents is total residential investment; this assumption is plausible, if we think that most of the investment in housing at the extensive margin is done by first-home buyers, who are typically constrained.

All the regressions that follow include an intercept term. The set of instruments is described below.

5.1. Reduced form evidence

I first report the estimate of Equation 4.5. I refer to this equation as 'reduced form', since it contains an estimate of the overall elasticities of consumption to house prices, interest rates, and housing demand, but not of the structural parameters of the model. As instruments, I use four lags of each right-hand side variable.[22] The resulting estimated equation (omitting the coefficient on the constant term) is given by (standard errors are in parentheses):

$$c_t = -\underset{(0.38)}{0.93}\, l_t + \underset{(0.11)}{0.44}\, q_t - \underset{(0.11)}{0.23}\, E_t q_{t+1} - \underset{(0.23)}{0.11}\, r_t + \underset{(0.02)}{0.09}\, h_t$$

Overall, the estimated consumption Euler equation appears in line with reasonable priors. The elasticity of consumption to the long real interest rate is negative and significant, while the short term interest rate has limited explanatory power and is not significantly different from zero. Moreover, the elasticity of consumption growth to current house prices is large, positive and significant. The long-run elasticity of consumption growth to house prices is smaller ($0.19 = 0.44 - 0.23$) and appears reasonable. Interestingly, such a number is also roughly in line with the VAR evidence presented in Section 2. Thus, at first pass, it appears that the new consumption Euler equation provides a reasonable description of consumption dynamics.

5.2. Structural estimates

I now redo the exercise in a way that permits to recover direct estimates of the structural parameters of the model, in particular λ, the share of consumption accruing to unconstrained agents, $1 + \omega$, the approximate inverse of the down-payment needed to purchase a house, σ, the elasticity of substitution of the unconstrained agents, and θ, which is related to the price elasticity of housing demand (more on this below).

One issue I have to confront is the fact that the econometric specification is nonlinear in the structural parameters of interest. A well-known issue is that nonlinear estimation using GMM is, in small samples, sensitive to the way the orthogonality condition is normalized. The orthogonality condition I choose is the

[22] Adding lagged consumption growth to the set of instruments did not affect the results.

one reported in equation 4.7. However, I estimated this equation using alternative sets of instruments.

The specification takes the form:

$$E_t \left\{ \left(c_t + (1-\lambda)\,\sigma\,(r_t + l_t) - \omega\lambda\,(q_t + r_t - E_t q_{t+1}) - \lambda q_t - \theta\lambda h_t \right) \mathbf{z}_t \right\} = 0$$

Estimates of the structural parameters and their standard errors are reported in Table 1. I report results using four different sets of instruments. In all the regressions, I also use one lag of the ratio household debt over personal disposable income (constructed from the Flows of Funds accounts) as an instrument. In column (1), the instruments are four lags of r, l, q, h. In column (2), I use as instruments four lags of $(r+l), (q+r-q_{+1})$,[23] (q) and (h), thus directly translating into the set of instruments the restrictions of the model. In column (3) I also use four lags of consumption growth as an additional instrument. Because of time aggregation worries, in column (4) I use instruments dated $t-2$ and earlier, so that there is at least a two-period time gap between instruments and variables in the estimated equation.[24] Although I do not report the results here, I also controlled for GDP or GDP growth in the specifications: the results were unchanged.

In all specifications, the results are similar. In general, the structural estimates tell the same story as the reduced form estimates.

The implied estimate of λ, the fraction of consumption accruing to constrained agents, ranges from 0.18 to 0.28 and is precisely estimated. This number is smaller than the numbers reported by Campbell and Mankiw (1989), who estimate the fraction of constrained consumers to be in the neighborhood of 0.4. Inspection of equation 4.6 also shows that λ is equivalent to the long-run elasticity of consumption to house prices. This confirms the similarity between structural and reduced form estimates.

The model also provides an estimate of how an increase in house prices translates into a short-run increase in consumption by allowing more borrowing. Depending on the specification, the estimate of $\frac{m\beta}{1-m\beta} = \omega$ is between 1.15 and 1.94, and is significantly larger than zero in all cases but one. Given that the model is estimated at quarterly frequencies, I can recover m, the implied loan-to-value ratios, assuming $\beta = 0.99$, as standard in the Real Business Cycle literature. The implied estimate m is then bound between 0.55 and 0.67. This estimate is quite sensible. While actual loan-to-value ratios for houses are somewhat higher

[23] To get around endogeneity problems, I lag $q + R - q_{+1}$ twice.

[24] See Campbell and Mankiw for a discussion (1989).

Dependent variable: $\Delta \ln$ consumption				
Estimates	(1)	(2)	(3)	(4)
λ	0.28	0.26	0.18	0.22
	(.07)	(0.08)	(0.06)	(0.13)
σ	0.64	0.56	0.40	1.00
	(0.16)	(0.17)	(0.10)	(0.24)
ω	1.15	1.23	1.68	1.94
	(.61)	(0.64)	(0.90)	(2.00)
θ	0.14	0.001	0.67	0.55
	(0.09)	(0.07)	(0.25)	(0.34)
Instruments	$r_{t-1},..r_{t-4}$ $l_{t-1},..l_{t-4}$ $q_{t-1},..q_{t-4}$ $h_{t-1},..h_{t-4}$ b_{t-1}	$(r+l)_{t-1} \cdots_{t-4}$ $(q+r\text{-}q_{-1})_{t-2}.._{t-4}$ $q_{t-1},..q_{t-4}$ $h_{t-1},..h_{t-4}$ b_{t-1}	$c_{t-1},..c_{t-4}$ $r_{t-1},..r_{t-4}$ $l_{t-1},..l_{t-4}$ $q_{t-1},..q_{t-4}$ $h_{t-1},..h_{t-4}$ b_{t-1}	$c_{t-2},..c_{t-4}$ $r_{t-2},..r_{t-4}$ $l_{t-2},..l_{t-4}$ $q_{t-2},..q_{t-4}$ $h_{t-2},..h_{t-4}$ b_{t-2}

Table 5.1: Regression Results, GMM estimates

The table reports GMM estimates of the structural parameters of Eq. 4.7. Estimates are based on quarterly data over the period 1986:1 - 2002:4. Robust standard errors are reported in parentheses.

(around 75-80% on average throughout the sample period, see for instance Gilchrist, 1997), they are within one standard error from the estimated coefficient. In addition, not all house prices changes lead to equity withdrawal. Moreover, actual lending criteria in the mortgage market are such that the borrower's income, besides collateral value, is a limiting factor in affecting the borrowing capacity of the agents and their ability to cash in equity gains. For these reasons, while the estimate of m is perhaps smaller than one would expect, it is very much in line with reasonable priors.

The estimate of the intertemporal elasticity of substitution for the unconstrained agents is also in line with expectations, and ranges from 0.4 to 1, which are all plausible. Finally, the range of estimates of θ goes from 0 to 0.67. If I take 0.33 as the average value, this translates into a long-run price elasticity of housing demand for the constrained agents which is in the neighborhood of $1/0.33 \approx 3$. I are unaware of studies that estimate a similar parameter, but I do not consider this number to be irrealistic.

The model also works well in the sense that I do not reject the overidentifying restrictions. Only in same specifications I found the point estimates to be slightly sensitive to the maximum lags of instruments included, as well as to the choice of the starting sample period. A thorough analysis of these issues is left for future research.

6. Conclusions

My results suggest that the Euler equation for consumption with borrowers whose credit capacity is constrained by their asset values may provide a reasonably good description of consumption dynamics.

It is interesting to relate my findings to the study by Jappelli and Pagano (1989). They study across countries how the sensitivity of consumption to current income is positively related to the size of capital market imperfections, as proxied by the loan-to-value ratios. They find that lower loan-to-value ratios lead to lower consumer debt, which in turn increases the sensitivity of consumption to current income. My structural econometric approach takes a slightly different route: first of all, I regard housing values more informative than income at the margin for the collateral capacity of the agents. Therefore, I can study the excess sensitivity of consumption to house prices, rather than to income. Secondly, since my estimation is backed by a fully-fledged general equilibrium model, I can recover directly estimates of m, the loan-to-value ratios, from the estimates of the elasticity of consumption to house prices, and still identify separately λ and

m. My emphasis is in the distinction between estimation of λ and estimation of m, something that the earlier literature has not emphasized. Causal observation of the US experience over the last decades suggests that λ might have fallen over time, but m might have increased, thus explaining large wealth effect from house price changes even in presence of a shrinking group of constrained agents.

To understand how house prices affect consumption, in other words, requires two ingredients: first, a model with heterogenous agents; second, an environment that specifies the link through which home equity gains can be transferred into higher borrowing and higher consumption. Earlier studies have deepened our understanding of the first step. This paper tries to close the gap with the second.

One important avenue to investigate involves looking at the trend as well as the cyclical behavior of the loan-to-value ratios. The assumption of a constant loan-to-value ratio might be at odds with the data over long periods,[25] especially since financial liberalization has led over time to an increase in the loan-to-value ratios for home-buyers, as well as to increased possibilities to cash in housing wealth for households. Indeed, as emphasized in the introduction, recent years have seen a rapid increase in both home lines of credit and traditional home equity loans, which have increased the liquidity of housing. It would be interesting to see whether extensions of the present framework along these lines can provide a better fit of the data.

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