Household Balance Sheets and Monetary Policy

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Abstract

Monetary policy may affect real consumer expenditures by lowering interest rates, raising incomes, or improving employment outlooks. This paper focuses on empirically identifying another important channel: homeowner balance sheets. A monetary loosening increases home values, thereby strengthening homeowner balance sheets and stimulating homeowner spending due to collateral or wealth effects. These effects vary substantially with local geography and regulation, as cities with the largest barriers to new construction see 3-4% responses in real house prices compared with unconstrained, elastic-supply cities where construction holds prices in check. Using non-public geocoded microdata from the Consumer Expenditures Survey, house price and consumption responses are compared across areas differing in local land availability and zoning laws to identify an average propensity to consume out of housing of 0.06. Homeowners with debt service ratios in the highest quartile have MPC's as high as 0.16 compared with negligible responses for those with low debt service ratios. This indicates a strong role for collateral effects in driving the relationship between home values and spending. While other channels explain initial variation in consumption after a monetary shock, variation in homeowner balance sheets explaining as much as 3-4.5% responses in consumption as house price responses peak after 10-12 quarters in the most inelastic-supply cities.

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1 Introduction

The collapse of the housing market between 2007 and 2009 left many homeowners with severely weakened balance sheets and unable to access credit markets. The impact of the recession on households is apparent in increased foreclosure rates, reduced mortgage lending, and reduced consumption growth during the period. At the same time, we have seen one of the largest scale monetary interventions in the history of the Federal Reserve System. An accurate assessment of the mechanisms by which monetary policy affects the real economy during deep balance sheet recessions is crucial to understanding the effects of such interventions.

While monetary policy may affect the real economy through a variety of channels (see Mishkin (1996) for a survey), the recent financial crisis has brought a new focus on the importance of borrower balance sheets for the propagation of macroeconomic shocks. Shocks that increase asset demand, such as a surprise monetary loosening, are amplified as asset prices increase, providing additional wealth and collateral to constrained borrowers. This is especially important in times when asset devaluation and debt overhang have left many borrowers unable to access credit. Increasing asset values provide collateral to constrained borrowers, mitigating agency costs between borrowers and lenders and allowing borrowers to finance higher levels of consumption or investment. While monetary policy may affect consumption and investment by increasing income expectations or lowering risk-free interest rates, the balance sheet channel amplifies small monetary shocks through large spending and investment responses from collateral constrained agents (Bernanke et al., 1999; Kiyotaki and Moore, 1997; Iacoviello, 2005). Though this mechanism has been described in the literature, there has been limited direct empirical evidence of its magnitude or importance for monetary policy transmission. The purpose of this paper is to empirically identify the balance sheet channel in a specific context: housing assets and homeowner balance sheets.

A monetary loosening lowers the user cost of housing, raising home values and strengthening balance sheets of homeowners. Improvement in homeowner balance sheet quality may have substantial impacts on real consumption expenditures due to wealth or collateral effects. I refer to this mechanism by which monetary policy affects real expenditures as the "homeowner balance sheet channel." This paper analyzes the quantitative importance of this channel by exploiting heterogeneity in local housing markets. In addition, the paper provides evidence for the relative importance of wealth and collateral effects in explaining the response of consumption to housing wealth fluctuations. The results provide direct empirical evidence for the importance of both local housing markets and homeowner balance sheets in the transmission of monetary shocks to real economic activity.

Housing markets are a natural laboratory for studying the impact of household balance sheet quality on consumption. Though housing is not the only collateralizable asset held by households, it is the most commonly used source of collateral. Furthermore, housing wealth forms a substantial portion of the household balance sheet, and even relatively small fluctuations in house prices can result in substantial changes in borrowing capacity. New homeowners, who are most likely to be younger and more credit-constrained, are most affected by housing market shocks due to their high level of leverage compared to older homeowners (Flavin and Yamashita, 2002). This makes housing an important source of collateral for smoothing consumption over the life-cycle, and one which can have large effects on the borrowing capacity and consumption of young, credit constrained households.

Additionally, differences in local geography and land-use regulations provide natural variation in the impact of a national-level shock on house prices in different cities. These variables have been shown to affect housing supply elasticity, and hence drive heterogeneity in housing market dynamics in various cities (Saiz, 2010). The importance of geographic and regulatory factors in driving heterogeneous price dynamics can be seen by examining the experience of various cities during the recent housing housing cycle in Figure 1. During the expansion period between 1996 and 2006, inland cities with few constraints on new construction, such as Dallas and Atlanta, saw little house price change and large levels of new construction. The collapse of the housing bubble halted new construction in these cities, but caused little collapse in house prices. Cities such as San Francisco, Miami, or New York, with limited land and stricter zoning laws saw limited new construction, but large fluctuations in prices during the same period.

This variation provides a natural means to identify the homeowner balance sheet channel. Since a monetary loosening shifts housing demand, house price responses vary systematically with local geography and land-use regulations. Regions that are unconstrained by geographic or regulatory factors have small responses in house prices as new construction keeps prices in check. Homeowners in these cities see little to no change in balance sheet quality due to the shock and are only affected through other channels. On the other hand, housing stocks cannot adjust easily in land-constrained and regulation-constrained regions, resulting in dramatic swings in house prices and hence home owner balance sheet quality. By comparing responses to monetary shocks across these types of cities, I identify the effect of monetary policy arising through household balance sheet fluctuations driven by house prices.

This paper quantifies the homeowner balance sheet channel in two steps. First, I identify the effect of monetary policy on real house prices and document the heterogeneity of house price responses in a structural vector autoregression (SVAR). The response varies substantially across metropolitan statistical areas (MSA's) with differing housing supply elasticity as measured by land availability and local zoning regulation variables from Saiz (2010). Second, I exploit this heterogeneity in housing markets to identify the propensity to consume out of housing wealth. Variation in cross-sectional house price responses caused by differing housing supply elasticity allows for the separate identification of the homeowner balance sheet channel and non-housing channels.

Evidence from a monetary SVAR shows that real house prices have a hump-shaped response to monetary shocks, peaking after approximately 10-12 quarters. Furthermore, house price responses are shown to differ substantially across housing markets. Land constrained and tightly regulated MSA's display a pronounced 4% response in house prices after a one standard deviation shock to Federal Funds rates. By contrast, highly elastic supply regions show little response in house prices as construction keeps price appreciation in check.

Using restricted-access geographic data from the Consumer Expenditure Survey, I link households to local housing supply elasticity measures (land availability and zoning regulations). Since local housing supply elasticity is unlikely to have direct effects on consumption, these variables are used to construct instruments for house price growth. This provides a means to compare the responses of consumption and housing between elastic and inelastic supply areas. Following a monetary loosening, consumption responses in a highly elastic-supply city will only reflect non-housing channels since house prices will be held in check by new construction. By comparison, a highly inelastic-supply market experiences large house price appreciation and a more pronounced consumption response in the presence of a homeowner balance sheet channel. Comparing consumption responses across these regions provides a measure of both the propensity to consume out of housing wealth and the total magnitude of the homeowner balance sheet channel.

The use of restricted-access geographic variables in the Consumer Expenditure Survey micro-data is crucial to the identification strategy used. Inclusion of county identifiers allows for household spending data to be linked to MSA and county-level variables on housing supply elasticity measures such as land availability and zoning laws (from Saiz (2010)) and local house price indices. This data makes this study unique since it is the first to use geographically linked micro-data on a broad set of consumption expenditures to identify the effect of housing wealth on spending. Previous studies on household collateral constraints have focused on the link between home equity and leverage by using geographically linked household credit data (Mian and Sufi, 2011). While some of the existing literature has attempted to use automotive loans or registrations as a proxy for spending (Mian et al., 2013; Kermani, 2013), the validity of extrapolating auto loans to total consumption is not clear. While the self-reported consumption measures used in this study are likely to be contain more noise than administrative credit or car registration data, they provide a more complete picture of household consumption-saving decisions over time.

In addition, direct measures of consumption better address the issue of substitution between forms of credit. For example, increasing home values may cause home equity-based credit to become relatively cheap compared to credit cards, school loans, etc. This may result in financing of activities through home equity that would have been otherwise undertaken with more expensive forms of credit. Such behavior is likely to have smaller macroeconomic impacts compared to increases in total credit or consumption. Furthermore, the CES data provides self-reported consumption measures and spans 1986-2012 and includes several business cycles providing a robust time frame compared with administrative credit data sets that span only the past decade. This provides evidence that the relationship between home equity and consumption, while most prevalent during the recent housing boom, has been stable over time.

Comparing household consumption responses across different local housing markets, I estimate the elasticity of consumption with respect to house prices to be 1.5 for homeowners. This corresponds to roughly a \$0.06-0.09 spending increase for a \$1 increase in home equity. In contrast, renters display a small and statistically insignificant consumption response to local house prices. This provides initial evidence that household balance sheets have a strong effect on spending.

The full empirical model describing the relationship between house prices, consumption, and monetary shocks provides a means to explore the channels through which monetary policy affects consumption. Estimated parameters are used to separately identify the homeowner balance sheet channel from other, non-housing channels. While homeowner balance sheet effects are small immediately after the monetary shock, the mechanism has an increasingly important effect as house prices rise over the course of 10-12 quarters after the initial shock. Homeowner consumption increases by 4-6% over this interval in the most inelastic-supply areas, whereas more elastic areas see smaller consumption responses due to only small house price fluctuations. Consumption responses are shown to primarily be driven by coastal cities and those in mountainous areas.

The relationship between housing and consumption is driven by a combination of collateral and wealth effects. While wealth effects may be large for a household who is selling housing in a high-price environment, these effects are likely to be reversed by negative wealth effects on home buyers. Since wealth effects are transfers between home buyers and home sellers, they have little effects on aggregate spending or welfare. By contrast, increases in home equity collateral improves borrower balance sheets and mitigates agency costs between borrowers and lenders. Collateral constrained borrowers are likely to have high propensities to consume out of housing since they are initially prevented from achieving their first-best consumption profile. Therefore, collateral effects are likely to increase aggregate consumption and welfare.

To test for the relative importance of the two effects, I compare responses of various types of households. First, I split the sample into "constrained" and "unconstrained" households based on the household's debt-service ratio (Debt service payments as percentage of income). High DSR values have been shown to be strong predictors of a household's likelihood of being denied credit and are hence a good proxy for credit constraints (Johnson and Li, 2010). Households in the top quartile of the DSR distribution are shown to spend roughly \$0.14 for every \$1 of home equity increase, whereas those in the bottom 75% display little response. This provides evidence that credit constrained households look to housing wealth to finance consumption.

To further test this claim, I split the sample between households which increased their home debt and those that did not. This provides a good measure of which households extract home equity to finance spending when their incomes fall. While these households are few in number, they drive the majority of the response in spending to house price changes. These households have a pronounced spending response of nearly \$0.30 for a \$1 consistent with the estimates for the propensity to borrow out of home equity estimated by Mian and Sufi (2011). This also provides strong evidence that, while wealth effects may play a role, collateral effects drive the relationship between house prices and consumption.

The importance of collateral effects in driving these relationships is crucial for the aggregate impacts of monetary policy. First, aggregate consumption responses are likely to be small if wealth effects were to dominate since wealth effects arise due to transfers of wealth between buyers and sellers of housing. The importance of collateral effects provides evidence that aggregate spending responses will be driven by large responses of constrained homeowners who enjoy increased collateral values. Secondly, the homeowner balance sheet channel provides a mechanism through which monetary policy may affect consumption inequality. Recent work by Coibion et al. (2012) finds that various measures of consumption inequality fall in response to a monetary loosening. By raising home values, a monetary loosening provides collateral to low income, credit-constrained households allowing them to finance higher levels of spending. Effects are small for high income, unconstrained households who have a low marginal value of collateral. The homeowner balance sheet, therefore, compresses the distribution of spending, reducing inequality.

The next section discusses the various data sets used in this study including the Consumer Expenditure Survey, housing supply elasticity measures, and house price indices. Section 3 discusses the effects of monetary policy on house prices and provides support for the empirical strategy and identifying assumptions described in Section 4. Section 5 discusses results and provides tests for the relative importance of collateral and wealth effects in explaining the homeowner balance sheet channel. Section 6 discusses related literature and the contributions made in this paper, and Section 7 concludes.

2 Data

Consumption Expenditures Survey (Public-Use and Restricted-Access Geography Data) The Consumer Expenditure Survey (CES) consists of quarterly interviews kept by respondents over the course of 5 quarters. The first interview is serves as an orientation for the household, and no expenditure data is collected. The 2nd through 5th interviews collect data on expenditures and household characteristics after which households are rotated out and replaced by new respondents. The unit of observation is a "Consumer Unit" (CU) defined as a financially interdependent group of people living in the same home and making joint expenditure decisions. A physical home may contain more than one consumer unit if members of the household make independent spending decisions on housing, food, and living expenses. For purposes of this study, I adopt the CU definition when referring to households that make consumption choices over time.

The CES sample frame is selected to form representative samples of each Census Region as well as 18 "Type A" metropolitan areas comprising most of the largest MSA's in the US. Sampling is also conducted at several smaller metropolitan and rural areas to form a nationally representative sample. Though the survey is not representative of any specific small geography, it provides nationally representative coverage of the local housing supply elasticities in cities where people live. Therefore, the consumption responses estimated using supply elasticity instruments can be interpreted as nationally representative.

A Census interviewer administers the quarterly Interview Survey in which households report demographic information and data on over 200 categories of expenditures. Assets and income data are only collected during either the 2nd or 5th interview. Notably, self-reported home values are only reported in the final interview, so house price growth cannot be observed within the survey. Quarterly summary expenditures values on total spending, non-durable spending,[1] and a variety of summary categories are generated for each household in the sample from 1986-2008.[2] Each expenditure category is deflated by the respective CPI. The sample period is selected to avoid major survey changes occurring prior to 1986 and the Zero-Lower-Bound (ZLB) period starting in December 2008 after which monetary shocks cannot be identified using Federal Funds rates. Households are linked across waves providing 4-quarter panels for each household.[3]

[1]Non-durable spending includes expenditures on food, alcohol, tobacco, housing operations, utilities, gasoline, public transportation, personal care, reading/entertainment, apparel, healthcare and educational expenses. Results are robust to excluding semi-durable or ambiguous categories such as apparel, healthcare, and education.

[2]Alternate specifications using county-level Zillow house price data use only 1996-2008 observations as this house price data is unavailable prior to 1996.

[3]Changes to the survey design in 1996q1 and 2005q1 prevent linking individuals across those two quarters.

In the restricted-access version of the CES, I match households with local-level housing market variables using FIPS county codes.[4] Identification rests crucially on the use of this geographic data. Household's who have lived in the same location for more than one year are matched to county and MSA level house price indices to provide a history of house price growth. In addition, these households are matched to measures of housing supply elasticity allowing consumption responses to be compared across households with differing exposure to house price growth. Finally, MSA-level annual per capita private income from the BEA is matched to households to provide an improved measure of local productivity growth.

Housing Supply Elasticity Measures Using restricted-access geographic variables in the CES, households are matched to local housing elasticity variables from Saiz (2010). The two measures of local housing supply elasticity are "proportion of unavailable land" and the Wharton Land-Use Regulation Index at the MSA-level. Taken together, these variables explain most of the across-MSA variation in housing supply elasticity (Saiz, 2010).

The measure of "unavailable Land" is constructed from topographic maps and measures the proportion of land in a 50km radius of the city center that is lost to steep slopes (above 15% grade) and bodies of water.[5] The definition considers land with a structure currently on it to be "available", so provides a time-invariant measure of total land, not currently unused land, available for construction. Therefore, the variable provides a limit on a necessary resource in housing construction and proxies for long-run elasticity in the MSA. Higher values of "unavailable land" imply larger geographic barriers to new construction, and therefore more inelastic housing supply.

The second measure, the Wharton Land-Use Regulatory Index constructed by Gyourko et al. (2008), is based on a national survey regarding the difficulty and cost of completing a residential construction project in various metropolitan areas. Survey measures attempt to capture the time and financial cost of acquiring permits and beginning construction on a

[4] This is done using a crosswalk from NBER to link counties to MSA's using the "old MSA" definitions.

[5] For further detail regarding the construction of the measure, refer to Section 2 of Saiz (2010).

new residential structure. The principal component of 11 survey measures used in the study is interpreted as an index for the stringency of local zoning laws.[6] The index provides a measure of how difficult it is to convert real resources such as labor, materials, and land into a house. Higher values of the index imply tighter regulatory barriers to new construction.

The use of metropolitan statistical areas as the relevant geographical area for defining local housing supply is not simply a convenience. MSA's are defined by the Office of Management and Budget based on economic and cultural dependencies. For example, commuting patterns may cause a certain county to be included into the larger MSA of its neighboring major city. This means housing is substitutable between counties within an MSA causing land unavailability or regulations in one county to influence prices of housing in neighboring MSA's. MSA-level housing markets are sufficiently isolated from each other by comparison, but do not vary substantially in geography and regulations compared to broader definitions such as states.

Both land availability and regulation variables are available only as a cross-section, which raises issues regarding their stability over the sample period. While local geography is constant over the sample period, regulations have changed. For example, many states in the Southwest tightened zoning laws to limit sprawl and control the area to which public resources (mainly water) is provided. Such changes would only bias results if cities that currently have inelastic supply formerly were amongst the most elastic-supply markets. Results using only the "unavailable land" measure as an instrument are consistent with baseline results suggesting that regulatory changes were too small to cause cities to move in the relative ordering of elasticities. Furthermore, Saiz (2010) shows that both land and regulatory measures predict housing supply elasticity remarkably well even when sample periods for elasticity estimation are constrained to various time frames between 1970-2010.

A related issue is migration during the sample period. For example, a systematic population shift from elastic to inelastic areas may change the relative likelihoods with which cities

[6] Further detail regarding the Wharton Land-Use Regulation Index can be found in Gyourko et al. (2008).

are sampled in the CES. Migration patterns from the American Community Survey's do not indicate any systematic migration patterns correlated with housing supply elasticity measures. Furthermore, the distribution of local housing supply elasticity variables in the CES sample is stable over time. While population shifts may affect sampling between cities, they do not affect the relative distribution of the population across elastic and inelastic supply MSA's.

House Price Indices Disaggregated house price data is essential to the identification strategy used in this study. The consumption response to house price changes is identified using local heterogeneity in house price increases which are not captured in state or regional indices. Additionally, the CES provides only a single observation of self-reported home values for each household. Therefore, I use non-public geographic data in the CES to merge households with local house price histories. This provides a means to understand how balance sheets and consumption behavior are affected by house price growth.

The preferred house price index used in this study is the all-transactions index produced by the Federal Housing Finance Agency (FHFA). House price indices are available quarterly from 1976-present for most MSA's in the United States. This provides both geographic coverage of nearly 80% of the U.S. population and a long time series that includes several business cycles, the recent national housing boom, and the New England regional housing bubble of the early 1990's. Each MSA-level index is constructed using a weighted repeat-sales method which compares transaction prices of homes to their previous sale price. By comparing each home to itself, this method avoids composition biases from quality changes in the stock of homes transacted from quarter to quarter.

While this index is attractive in its geographic scope and relatively long time series, it suffers a fundamental drawback. The FHFA indices are constructed using transactions data acquired through Freddie Mac, and hence cover only homes purchased with conforming mortgages. Aside from cash transactions, this excludes all sub-prime, jumbo, and other non-traditional loans which were largely responsible for the rapid house price growth in the mid-2000's, especially in inelastic supply regions (Barlevy and Fisher, 2010; Mian and Sufi, 2009). This causes the FHFA index to understating the the sensitivity of house prices to alternative credit in the inelastic-supply regions which may be linked to loose monetary policy.

To address this issue, I also estimate the baseline specification using an alternate index from Zillow.com. Unlike FHFA's repeat sales method, Zillow uses a proprietary hedonic pricing model to estimate the value of most US homes based on home characteristics and price data collected from county registrars, real-estate agencies, and self reports. These individual home value estimates are then averaged into county, MSA, state, and national level indices. Like the repeat-sales methodology, the Zillow index does compare a home's "zestimate" with its past value to avoid composition biases. Furthermore, Zillow estimates each house price in a manner similar to repeat-sales methods to address composition biases in the stock of transacted homes.[7] Despite its superior coverage of homes and availability at the county level, the Zillow house price index extends only back to 1996 and covers only one housing cycle and two NBER recessions. Use of both FHFA and Zillow indices provides a robust estimate for the homeowner balance sheet channel.

Since house prices are only observed once for each household during much of the sample period, house price growth cannot be constructed using self-reported values. Using the restricted-use geographic data in the CES, I link each household to local house price histories using the FHFA and Zillow indices. Figure 4 provides a comparison of national-level indices from FHFA, Zillow, and Case-Shiller along with mean and median self-reported home values from the CES. Self-reported values closely track the house price indices used in this paper.

Macroeconomic Variables In order to identify national-level credit and monetary shocks, I use a time series of macroeconomic variables in a recursive vector autoregression. Variables include log real GDP, CPI inflation, effective federal funds rates, 30 year conventional

[7] A thorough discussion of the methodology can be found on Zillow's Research website: http://www.zillowblog.com/research/2012/01/21/zillow-home-value-index-methodology/

mortgage rates, and the national house price index (FHFA all transactions) at a quarterly frequency from 1954-2012.

3 Monetary Policy & House Price Dynamics

Since the propensity to consume out of housing will be identified using cross-sectional differences in house price responses, it is instructive understand the impact of monetary policy is on local house prices and how this differs across cities. The "homeowner balance sheet channel" requires that monetary policy shifts house prices, resulting in strengthened homeowner balance sheets. Furthermore, the heterogeneity in price responses is crucial to the identification. Land availability and regulation variables will be used to compare house price and spending responses to monetary shocks across regions. The difference between elastic-supply MSA's with little house price response and inelastic-supply MSA's with larger price response provides insight into the importance of homeowner balance sheets in the transmission of monetary shocks. Without heterogeneity in price responses, identification of this channel will be weak.

Monetary policy affects the user cost of housing, shifting demand.[8] This increases housing starts and higher home values. The relative increase in construction and price driven determinants of housing supply elasticity such as land availability and zoning laws. After a monetary shock, MSA's with limited "buildable" land will have increasing marginal costs of new construction resulting in higher house prices relative to land-rich areas. Similarly, in MSA's with stricter zoning regulations, new construction will be costly, raising the marginal value of an existing home.

To provide a simple means of empirically identifying this heterogeneity in house price responses, I use a simple monetary vector autoregression (VAR) to estimate impulse responses

[8]While housing supply may also be shifted by monetary shocks due to financing constraints on home builders, house price responses will be correlated with housing supply elasticity variables so long as monetary policy shifts demand more than supply. The relevance of instruments used rests on house prices responding relatively more in areas with limited land and strict zoning laws. Empirical results indicate that this is the case, implying shifts in housing supply following a monetary shock are quantitatively small.

of house prices to monetary shocks in different areas. Using housing supply elasticity estimates of house prices from Saiz (2010), I combine MSA-level FHFA house price indices (henceforth HPI's) into 4 indices for quartiles of the elasticity distribution weighted by population.[9] A VAR is then estimated using national GDP, CPI inflation, Fed Funds rate, 30yr Fixed Mortgage Rate, and the four constructed quartile HPI's. Baseline identification of monetary shocks allows Fed Funds rates to respond contemporaneously to GDP and inflation, but to mortgage rates and HPI's only with a lag.

The assumption that GDP and inflation are predetermined in the Fed's policy rule is standard in the literature. This is supported by the fact that production and pricing decisions are often made in advance and are difficult to change on the fly. Prices of goods in the CPI are changed approximately once every 4-7 months (Bils and Klenow, 2004; Klenow and Kryvtsov, 2008), and hence are planned in advance and unlikely to respond to changes in monetary policy or financial markets within a quarter.

While the ordering of GDP, inflation, and Fed Funds is standard, the inclusion of housing variables is not. The Fed Funds rate is ordered prior to mortgage rates and house prices, therefore restricting the Fed from responding to end-of-quarter mortgage rates and house price indices. Financial markets are quick to respond to monetary policy movements, hence long-term mortgage rates are likely to react to monetary shocks within the quarter. Furthermore, house prices are determined at the time of transaction and hence are based on the full information sets of the transacting parties at the time the sale occurs. Therefore, house prices likely reflect concurrent movements in monetary policy. Since only monetary shocks are identified, relative ordering of other variables does not affect the identification of impulse responses to monetary shocks (Bernanke and Blinder, 1992; Christiano et al., 1999).

Resulting impulse responses for each quartile are plotted in Figure 6. As can be seen in the first panel, the most elastic cities show little house price response to a monetary shock

[9] Cities are partitioned into population-weighted quartiles based on housing supply elasticity estimates. House price indices q_{it} for MSA's i at time t are combined using population weights ω_i from the 2000 Census: $Q_{mt} = \frac{\sum_{i \in m} \omega_i q_{it}}{\sum_{i \in m} \omega_i}$.

with approximately 0.5-1% decline in house prices over 3-4 years after a 1 standard deviation (71 basis point) shock to Federal Funds rates. As housing supply elasticity falls, house price responses become more dramatic. The most inelastic areas display a house price response of 3-4% from trend after 3-4 years after the same shock.

Closer analysis of the underlying VAR reveals that monetary shocks move 30 year fixed mortgage rates causing a shift in housing demand. While housing supply may also shift, the crucial identifying assumption that house prices respond heterogeneously to monetary shocks is supported by these results. Chapter 1 provides further analysis of this phenomenon on both house prices and residential investment. Results provide further evidence that monetary shocks shift housing demand along heterogeneous local housing supply curves.

These results provide not only an insight into the distributional effects of monetary policy, but also a means to identify the homeowner balance sheet channel. While the most elastic-supply locales see little house price response to monetary shocks, the effect is pronounced in more inelastic areas. Under the assumption that homeowner consumption behavior does not depend directly on determinants of housing supply elasticity, homeowners in elastic or inelastic areas are ex-ante similar. Following the shock, only those in inelastic cities enjoy increased home equity while both are affected by non-housing channels such as increased income and employment or lower interest rates. Differencing across areas provides a means of understanding the importance of housing and balance sheet effects in the transmission of monetary shocks. The following section formalizes this intuition and provides conditions under which the homeowner balance sheet channel is identified.

4 Empirical Specification

The goal of this paper is to estimate the "homeowner balance sheet channel" of monetary policy. Non-durable consumption responses to monetary shocks will be decomposed into the component arising due to fluctuations in housing wealth and those arising through other channels. The balance sheet channel will be separated by first identifying monetary shocks orthogonal to any endogenous policy responses to current or anticipated economic conditions. These shocks will then be used to identify the effect of monetary policy on house prices and non-durables spending across regions with differing housing supply elasticity. After a monetary shock house prices in the most elastic-supply MSA's are held in check by new construction and homeowners are only affected by non-housing channels. On the other hand, inelastic-supply MSA's see large house price responses and homeowners are affected both by housing wealth increases and other non-housing channels. Comparing these regions allows for a decomposition of the total consumption response to monetary policy into it's homeowner balance sheet component and it's non-housing component.

The intuition for the identification strategy is to difference household-level consumption responses to monetary shocks across households in different housing supply elasticity regions. The general procedure first identifies and estimates monetary shocks using a recursive vector autoregression. This provides a measure of deviations of Federal Funds Rates from the endogenous policy responses prescribed by a Taylor rule. These shocks are then combined with land availability and zoning regulation measures to estimate consumption and house price responses to monetary shocks in the Consumer Expenditure Survey (CES). Using an instrumental variables approach, I compare these responses across MSA's with different housing supply elasticity to identify the propensity to consume out of housing, house price responses to monetary shocks, and the homeowner balance sheet channel.

Monetary shocks are identified as in Bernanke and Blinder (1992) using a recursive ordering. The VAR includes log-real GDP, CPI inflation, federal funds rate, 30 year mortgage rate, and the log-real national house price index. As in Section 3 the federal funds rate is allowed to respond to log-real GDP & inflation concurrently, but can be affected by mortgage rates and house prices with a lag. Mortgage rates and house prices are allowed to respond quickly to innovations in other variables including monetary policy. Financial markets react to new information quickly and end of quarter 30-year mortgage rates likely reflect changes in monetary policy during the quarter. Similarly, house prices are set at the time of sale and likely reflect all information known to the transacting parties including recent monetary shocks. Identified monetary shocks are displayed in Figure 5.

Household i's log real non-durable consumption growth $\Delta c_{i,t+1}$ and log real house price growth $\Delta q_{i,t+1}$ are modeled as:

$$\Delta c_{i,t+1} = \beta_1 \Delta q_{i,t+1} + \beta_2(L)\eta_t + \beta_3 \Delta x_{i,t+1} + u_{i,t+1} \tag{4.1}$$

$$\Delta q_{i,t+1} = \gamma(L)\eta_t + \gamma_4 \Delta x_{i,t+1} + v_{i,t+1} \tag{4.2}$$

where η_t is the monetary shock[10] and $x_{i,t+1}$ is a set of household-level controls including age, family size, and income. The empirical model is estimated in first-differences, and hence allows for unobserved heterogeneity in consumption levels due to household-specific tastes. Appendix A formalizes the assumptions under which a vector of household-level variables follow a distributed lag of monetary shocks (ie, a "partial" Wold Decomposition exists).

Identification of the model provided in (4.1) and (4.2) provides insight into a number of objects of interest. The coefficient β_1 provides a measure of the elasticity of non-durable consumption to housing wealth. The magnitude of this coefficient provides insight into how households use housing assets to smooth consumption over their lifetime. Furthermore, the system provides a means to understand the effects of monetary policy on consumer expenditures and housing wealth. This can be seen by taking the total derivative of consumption

[10] The lag-order on $\beta_2(L)$ and $\gamma(L)$ are selected to be 20 quarters. Since the procedure used directly estimates the impulse response from the Wold Form, a sufficiently long lag order is necessary to capture the full dynamic response of house prices following a monetary shock. Inclusion of only monetary shocks near the peak-response period of 8-16 quarters does not affect results.

and house price growth with respect to a monetary shock yields:[11]

$$\frac{d\Delta c_{i,t+1}}{d\eta_{t-h}} = \beta_1 \frac{d\Delta q_{i,t+1}}{d\eta_{t-h}} + \beta_2(h) + \beta_3 \frac{d\Delta x_{i,t+1}}{d\eta_{t-h}} \tag{4.3}$$

$$\frac{d\Delta q_{i,t+1}}{d\eta_{t-h}} = \gamma(h) + \gamma_3 \frac{d\Delta x_{i,t+1}}{d\eta_{t-h}} \tag{4.4}$$

The total derivative captures the effect of monetary policy on consumption growth at various lags, in a manner similar to an impulse response function. The equations above also shed light on the various channels through which monetary policy affects consumption.

The homeowner balance sheet channel is captured in the first term of (4.3). This term combines the effect of monetary policy on house prices $\frac{d\Delta q_{i,t+1}}{d\eta_{t-h}}$ given in (4.4) and the effect of house prices on spending β_1. Not surprisingly, the magnitude of this channel is determined largely by the propensity of the household to spend out of housing wealth β_1. If the homeowner's spending does not respond to increases in housing value, it is unlikely that balance sheet effects will matter in the transmission of monetary shocks to homeowner spending. Therefore, identification of β_1 is crucial to identifying the homeowner balance sheet channel.

The remaining terms, $\beta_2(h) + \beta_3 \frac{d\Delta x_{it}}{d\eta_{t-h}}$, capture non-housing effects of monetary policy. These may include indirect effects through control variables such as income or effects on spending through channels not explicitly included in the specification.

4.1 Identification

The marginal propensity to consume out of housing, β_1, cannot be identified using the model as specified. Consumption growth, Δc, and house price growth, Δq, are simultaneously determined. Furthermore, all covariates in the specification above appear in both equations violating the order condition. A monetary shock causes changes in both house prices and consumption growth, but the effect on consumption due to the homeowner balance sheet channel cannot be identified since both variables move together. This issue highlights the

[11] As discussed in Appendix A, monetary shocks η_t are orthogonal to $u_{i,t+1}$ and $v_{i,t+1}$since the latter are sums of non-monetary structural shocks.

importance of micro-data in addressing the issue of simultaneity in these variables. Cross-sectional variation in the responses of consumption and housing values can provide some insight into the causal link between the two.

Secondly, the error terms $u_{i,t+1}$ and $v_{i,t+1}$ capture unobserved national and local shocks. This means $u_{i,t}$ and $v_{i,t}$ are correlated with each other, resulting in an omitted variables bias in (4.1). For example, a shock to productivity raises wealth causing a simultaneous increase in both spending and house prices. Estimation by OLS results in overstating the causal effect of housing wealth on spending since the effect of unobserved productivity shocks will be partially attributed to housing wealth.

This paper exploits MSA-level heterogeneity in housing markets to consistently estimate β_1 using an instrumental variables estimator. Since monetary shocks η_t will shift housing demand, I allow the effect of monetary shocks on house price growth to vary with determinants of housing supply elasticity: land availability and local land-use regulations. I also allow for local house price trends to directly depend on these local supply elasticity measures. In the context of the model presented above, the coefficient on η_t in (4.2) becomes $\gamma(L) = \gamma_1(L) + \gamma_2(L)z_i$ where z_i is a vector of "unavailable land" and Wharton Land-Use Regulation measures in the household's MSA.[12] This yields:

$$\Delta c_{i,t+1} = \beta_1 \Delta q_{i,t+1} + \beta_2(L)\eta_t + \beta_3 \Delta x_{i,t+1} + u_{i,t+1} \tag{4.5}$$

$$\Delta q_{i,t+1} = [\gamma_1(L) + \gamma_2(L)z_i]\,\eta_t + +\gamma_3 z_i + \gamma_4 \Delta x_{i,t+1} + v_{i,t+1} \tag{4.6}$$

The interaction between supply elasticity and demand shocks, such as monetary shocks, determines the magnitude of $\Delta q_{i,t+1}$. As discussed in Section 3, monetary shocks shift housing demand causing local house price q_{it} changes to be proportional to the land availability and zoning laws. This provides support for the relevance of the excluded instruments in the model.

Excluded instruments, z_i and $\eta_t z_i$, provide a means to identify β_1, the response of con-

[12]Details regarding these measures are provided in Section 2.

sumption to changes in housing wealth. Using an IV estimator, impulse responses of consumption and house prices are compared across high and low elasticity housing markets. This provides cross-sectional variation in the magnitude of house price responses which affect consumption behavior through β_1. Identification requires that housing supply instruments do not have direct effects on consumption. Formally, the set of orthogonality conditions required for identification of the full system in (4.5) and (4.6) is:

$$\eta_{t-h} \perp u_{i,t+1}, v_{i,t+1} \tag{4.7}$$

$$z_i \perp u_{i,t+1}, v_{i,t+1} \tag{4.8}$$

$$\Delta x_{i,t+1} \perp u_{i,t+1}, v_{i,t+1} \tag{4.9}$$

Assumption (4.7) follows from the identification of monetary shocks in the structural VAR. Since monetary shocks are orthogonal to other structural shocks, it follows that $\eta_t \perp u_{it}, v_{it}$. This highlights the importance of "purging" Fed Funds innovations of endogenous policy responses to non-monetary shocks. Failing to do this would cause monetary shock measures to be correlated with non-monetary structural shocks appearing in $u_{i,t+1}$ and $v_{i,t+1}$.

Assumption (4.8) requires that land availability and zoning regulations are uncorrelated with consumption growth conditional on monetary shocks, η_{t-h}, and other covariates, Δx_{it}. Though it is unlikely that consumption growth is directly affected by the availability of land or zoning laws in a given city, one might be concerned that inelastic cities tend to attract a different type of consumer than more elastic cities. Nonetheless, closer inspection reveals that this is not the case. First, while consumers in relatively inelastic cities such as New York and San Francisco tend to have higher levels of consumption, income, and housing wealth, the specification above only requires that they do not have higher growth in consumption. Furthermore, demographic characteristics between "elastic supply" and "inelastic supply" MSA's displayed in Table 1 show that households in the highest, middle, and lowest thirds of the elasticity distribution appear similar in observable characteristics overall. Several observable factors that may vary between cities are controlled for by the inclusion of income growth, changes in family size, and age.

A second worry is that inelastic supply cities may be larger or more socially desirable and hence may attract households with differing consumption patterns. This is only a concern if consumption growth varies systematically across housing supply elasticity variables. Results show little effect for renters in both regions, indicating such selection issues are unlikely. This concern is also allayed by closer inspection of cities across elasticities, land availability, and zoning laws listed in Table 2. Several smaller coastal or mountain cities such as Galveston, Texas, and Eugene, Oregon, appear on the list of most inelastic MSA's. Furthermore, large MSA's such as Atlanta, San Antonio, and Oklahoma City are amongst the most elastic supply cities. Overall, the correlation between MSA population and land availability is only 0.086 while the correlation between population and zoning regulations are slightly higher at 0.209. Alternate specifications excluding zoning regulations from the regression yield in quantitatively similar results for the magnitude of the homeowner balance sheet channel.

Another issue that may cause housing supply elasticity to be correlated with consumption growth is that the magnitude of local housing demand shocks varies systematically with housing supply elasticity. This is likely to be the case based on evidence in the literature. For example, Glaeser et al. (2008) show that inelastic housing supply markets are more prone to severe asset bubbles causing both current and future house prices to rise. The increase in expected house price appreciation lowers user cost and raises expected collateral values 2-3 years in the future. This may induce "alternative" lending behavior such as interest-only or low down payment mortgages in areas with high anticipated price growth (Barlevy and Fisher, 2010). Such amplification of credit shocks due to future price growth cannot be addressed in the given specification. While this may overstate the importance of current house price growth in explaining consumption growth, the total response to monetary policy acting through housing markets is identified. The homeowner balance sheet effect identified in this paper incorporates both the increase in concurrent housing wealth and alternative credit due to future price increases in inelastic-supply cities.

Finally, the inclusion of variables $\Delta x_{i,t+1}$ attempts to control for a variety of factors that may influence both house prices and spending. First, life-cycle variables are included to control for discrepancies in homeowner age and family structure between elastic and inelastic supply MSA's. For example, if homeowners sampled in inelastic areas tended to be older than those in elastic supply areas, one may observe differential consumption growth between elastic and inelastic markets arising due to life cycle effects, not housing wealth. Conditioning consumption growth on a polynomial of household age and family size (OECD adult-equivalent scale) prevents this type of error. While homeowner demographics in the sample are broadly similar across elasticities, the specification avoids attributing cross-MSA differences in consumption growth driven by demographics to housing wealth fluctuations.

A second issue is conditioning on household or local income growth. The importance of controlling for these factors can understood by considering a local productivity shock such as the introduction of "fracking" providing means to cheaply access natural gas deposits in Western Pennsylvania. By improving the employment outlook and lifetime wealth of residents, this type of shock stimulates both housing demand and non-durable spending in the MSA. Ignoring this source of endogeneity would overstate the causal relationship between home equity and spending. This bias is partially addressed through the instruments, since it is unlikely that local productivity shocks are correlated with land availability or zoning laws. Conditioning on local income growth controls for any concurrent changes in local productivity or economic conditions that may be correlated with the elasticity instruments. Both household and MSA income growth are included to control for household-specific and regional economic fluctuations that may drive both spending and housing demand.

In addition to exogeneity assumptions on instruments used, another key assumption is that the excluded instruments is sufficiently strong predictors of Δq. If monetary shocks do not affect real house prices differentially across elastic and inelastic supply housing markets, identification may be weak resulting in non-normal asymptotic distributions of the 2SLS estimator and poor coverage probabilities of confidence intervals. As described in Section 3, monetary loosening causes national-level house prices and housing starts to rise. Furthermore, inelastic MSA's see increases in house prices of 4-6% over the course of 8-10 quarters while the most elastic-supply MSA's see little movement in real house prices. This provides evidence that there is substantial variation across MSA's in the response of house prices to monetary shocks. Furthermore, LIML and 2SLS procedures provide similar estimates and first-stage F-statistics from the baseline specification exceed the Stock & Yogo (2001) thresholds for relative bias of 10%.

A final econometric issue is the appropriate correction of standard errors to account for generated regressors. The procedure first estimates monetary shocks, $\hat{\eta}_t$, and then treats these as data in the 2SLS estimation of (4.5) and (4.6). This ignores estimation error in $\hat{\eta}_t$. Under regularity conditions discussed in the Appendix B, the generated regressors do not affect consistency of parameter estimates, but will affect the consistency of the standard errors (Wooldridge, 2002; Murphy and Topel, 1985; Pagan, 1984). Regularity conditions and adjusted standard errors are described in Appendix B.

The identification strategy used here provides a consistent estimate of β_1, the elasticity of consumption to house prices. This elasticity of non-housing consumption to housing wealth has been studied by others in the literature Case et al. (2005); Cooper (2009); Campbell and Cocco (2007), but the specification used here provides a novel instrument that better controls for endogeneity in house price growth. In addition to baseline results estimating the relationship between home values and spending, I present two extensions attempting to test for the relative importance of collateral and wealth effects.

Secondly, taking the system as a whole provides a decomposition of consumption responses to monetary shocks into the baseline effect and the amplification that occurs through homeowner balance sheets. As discussed previously, the parameter β_1 along with the response of house prices to monetary shocks from the first stage determine the magnitude of consumption responses arising through homeowner balance sheet effects. This provides insight into the importance of collateral and balance sheet quality in propagating and amplifying monetary policy to the real economy. Furthermore, it provides a measure of the regional wealth transfers and inequality that occur due to monetary and credit shocks.

5 Results and Discussion

5.1 Consumption Response to House Prices

Table 3 provides estimates from this baseline specification home owners, owners with mortgages, renters, and the combined sample of all households. Results show that the consumption elasticity to housing wealth,β_1, is positive and significant and roughly 1.5 for owners. These results provide strong evidence that housing wealth plays a substantial role in amplifying consumption responses to monetary shocks. Given the mean (nominal) home value in-sample of approximately \$200k and mean quarterly non-durable expenditures of approximately \$9.3k, homeowners increase quarterly spending by \$0.06-0.09 for a \$1 increase in home equity within the quarter. These results are in line with related estimates in the literature. For example, Cooper (2009) finds a propensity to consume \$0.06-0.18 per \$1 increase in housing wealth using data from the PSID. Related work by Mian and Sufi (2011) find a propensity to borrow \$0.25 cents for \$1 of house price growth during 2002-2006. MPCs estimated in this paper are slightly smaller than this number, implying that not all of this equity extraction is spent within the CES interview period and may result in increased savings in the short-run. Furthermore, Barlevy and Fisher (2010) provide evidence that unconventional forms of leverage grew substantially in the mid-2000's in areas of expected price growth such as California, likely indicating that the sample period used by Mian and Sufi (2011) is one in which asymmetric leverage growth between elastic and inelastic-supply areas was large due to expected future house price appreciation.

Unlike homeowners, renters (non-owners) do not enjoy strengthened balance sheets or increased wealth due to rising home values. This is supported by low and insignificant elasticities of consumption to house price changes in the "renters" column in Table 3. While estimates of β_1 are slightly negative for renters, they are not significantly different from zero. While one may expect negative wealth effects for renters who plan to purchase housing in the future, these effects may be small due to the ability to adjust the timing or size of future home purchases. Furthermore, rising home values may cause purchase prices to be high, but may also result in laxer lending standards as home equity is expected to rise.

Moreover, the negligible effects on renters compared to those for owners highlights the dual role of housing as wealth and collateral.[13] A house's price is determined by the present value of flow rental payments. Even if the house is occupied by the owner, the owner forgoes the rental payment, or alternately can be perceived as implicitly "renting to herself". An increase in house prices implies the present value of rental payments has risen, increasing the wealth of the household but simultaneously increasing the cost of living. The net wealth effect is likely to be small unless the household is a net-buyer or net-seller of housing. Furthermore, wealth effects arise simply from a transfer of wealth between buyers and sellers of housing, and are likely to be symmetric in the absence of collateral constraints. The large effect on owners compared to renters likely indicates the importance of collateral effects.

The importance of this often subtle distinction between wealth and collateral effects can be seen by thinking about the source of collateralized lending. Agency costs between the borrower and lender often arise since the lender cannot easily enforce repayment. In such a case, the borrower may post collateral to insure the lender against default. The value of collateral becomes an essential state variable in determining the amount of credit that can be secured. If the household has insufficient collateral to meet its borrowing demand, the lender will not provide additional credit despite the fact that the household has the capacity to repay the loan. Such a market failure can be avoided by providing the household with additional collateral, as is the case when home values rise. This is especially important since

[13] Adjustment costs make it unlikely that a small change in house prices, such as those arising from monetary and credit shocks, will induce a household to move. Given that house prices respond by at most 4-5% given a 1-standard deviation shock to Federal Funds, the substitution effects between housing and non-durables are ignored from this discussion.

higher collateral values mitigate agency costs and are welfare improving.

Furthermore, the magnitude of collateral effects is likely to be large compared with wealth effects. Unconstrained households are able to equalize marginal utility across time. Loosening collateral constraints will have little to no effect on current consumption as the unconstrained household is already able to smooth consumption over time. Alternately, a household with low home equity may not have access to its desired borrowing capacity due to limited collateral. This drives a wedge between marginal utility of consumption today and next quarter, leaving the household wishing it could borrow more. Higher home equity collateral provides such a household with borrowing capacity and can have dramatic effects on consumption.

Identifying collateral constrained households is a challenge. The distinction between "constrained" and "unconstrained" becomes somewhat blurred in the presence of risk. A household with a loan-to-value ratio near the collateral limit may choose to conserve some debt capacity as insurance against a negative shock. This precautionary savings motive affects a household that may not appear to have maxed out their borrowing limit, blurring the line between feeling the effect of the constraint and having it bind in the current period. Put differently, the likelihood of the constraint binding in the future causes the household to behave differently in the present Carroll and Kimball (1996). This effect diminishes as the loan-to-value ratio becomes substantially smaller than the collateral limit, since the likelihood of the constraint binding in the future falls. Therefore, in reality, households fall on a spectrum between constrained and unconstrained. Since the shadow value of the constraint is not directly observable, this paper follows the approach of the literature (Zeldes, 1989; Cooper, 2009; Johnson and Li, 2010) in identifying the level of credit constraints through observed balance sheet and debt payment variables.

Several common ratios are used both by academics and banks to assess credit risk and credit constraints. The choice of an appropriate ratio in this paper is motivated by the strengths of the data used and the nature of lending behavior during the time. The primary function of the Consumer Expenditure Survey is to construct the CPI and summary tables of expenditures released by the BLS. The survey is designed to measure expenditure with relatively high precision, while partial balance sheet data is only collected in the first and last wave with substantial mis-reporting. Furthermore, households are more likely to recall periodic payments made on debt rather than the outstanding balance. This motivates the use of debt service payments, including all payments to interest and principal on debt obligations (primarily mortgage and car loans), rather than outstanding debt values. A common ratio used by banks to assess credit quality is the Debt-Service Ratio (DSR), defined as the ratio between debt service payments and after-tax income. This measure both exploits the strengths of the data set used and has been shown to predict the likelihood of being denied credit (Johnson and Li, 2010). Households falling in the top 25% of non-missing DDS's are flagged as "constrained" while those in the bottom 75% are flagged "unconstrained."

An alternative test for the importance of collateral effects is to directly look directly at collateralized borrowing. Households who increased their home equity-based debt are accessing the collateral in their homes in order to either pay down other debt, save, or increase consumption. I flag these households as "equity extractors" in comparison to those that did not extract home-equity and compare their propensity to consume out of housing wealth with that of other households. While equity extraction may not be exogenous, households who access home equity in response to (temporary) negative income shocks are likely to decrease spending, biasing the difference between "equity extractors" and "non-extractors" downwards. Results indicating a higher propensity to consume for equity extractors will still suggest a strong role for collateral effects in driving the relationship between housing and spending.

Testing if the elasticity of consumption to house prices, β_1, of constrained households is larger than the baseline estimate provides a means of checking the importance of credit constraints as opposed to wealth effects. Results from the credit constraints model can be found in Table 4. To put the results in perspective, an individual in the highest quartile of Debt Service Ratios has an elasticity of consumption to housing wealth of 3, roughly double that of the baseline estimate found in column 1. By comparison, unconstrained households in the bottom 75% of debt-service ratios have slightly negative, but insignificant, spending responses to house price changes.

Results for those increasing home debt are seen in columns 4 and 5 of Table 4. Households who extracted home equity have an estimated elasticity of 3.56, over twice as large as "non-extractors." While the inter-relationship between refinancing, house prices, and spending is complex, this result provides evidence that home-equity-based borrowing is a very important driver of the relationship between home values and non-durable spending.

These results are useful in understanding the implications of monetary policy for inequality. Recent work by Coibion et al. (2012) uses the CES to show that monetary loosening can reduce measures of consumption and income inequality. My finding that collateral effects drive the relationship between house prices and spending provide a specific mechanism through which monetary policy may affect inequality. By raising house prices, a monetary loosening provides constrained homeowners with collateral. This allows low-income, constrained households with the means to finance spending and smooth consumption. In contrast, richer, unconstrained households have little to no response in spending since their marginal value of collateral is small and wealth effects are negligible. This compresses the cross-sectional distribution of spending, reducing inequality.

Table 5 provides evidence that these results are robust to several alternate specifications. First, it is possible that returns on assets other than housing may affect consumption growth, and the omission of these factors causes an upward bias on the propensity to consume out of housing. This is unlikely to be the case given that asset holdings and asset returns are uncorrelated with measures of housing supply elasticity. Furthermore, column 1 shows that estimated elasticities for owners are unchanged by the inclusion of these variables.

As discussed previously, conditioning on income growth prevents spurious results arising from local productivity or wealth changes that may affect both housing demand and non-durable consumption. Baseline results include household after-tax income growth and MSA per capita income growth measures. Column 2 provides estimates using only household income with little change to estimates. The consumption response to household income remains low while the response to housing is rather high. Since the CES collects pre-tax income and income taxes separately, pre-tax income is likely to be measured with less noise than after-tax income. Using pre-tax income is shown to have little effect on estimates in Column 3.

Conditioning on concurrent income growth may not reflect anticipated changes in productivity growth that may affect consumption and housing demand in the MSA. Since income expectations are not observed, column 4 re-estimates the model including realized income growth over the next year. While household's may not have perfect foresight, their forecasts are likely to be centered at the true values of income growth. Results including expected income growth reduce the magnitude of the estimated response to house prices slightly, but households still increase consumption substantially in response to an increase in home equity.

Table 5 also repeats the baseline estimation using the county-level Zillow Home Value Index. While this constrains the sample period to 1997-2008, the measure offers a variety of benefits over the baseline FHFA house price index.[14] First, Zillow home values are available at finer geographic levels than FHFA indices. While land and regulation instruments are still MSA-level measures, using county-level price data allows house price growth the first stage to be weighted appropriately based on the areas within an MSA in which the household lives. Secondly, Zillow price indices are constructed using transactions data from all homes in the regions covered, whereas FHFA indices rely on data on conforming mortgage loans acquired from Fannie Mae and Freddie Mac. The inclusion of non-conforming loans, such as jumbo mortgages or subprime loans, accounts for a large amount of variation in prices during the late 1990's and early 2000's. As indicated in Figure 4, Zillow home values move more dramatically than FHFA indices during this period and are likely more sensitive to monetary shocks. This is reflected in slightly lower estimates of consumption responses to Zillow house

[14] Further details regarding differences in the construction of the Zillow Home Value Index (ZHVI) and FHFA house price index are presented in Section 2.

price changes compared with baseline results using FHFA indices as seen in by comparing column 5 to column 1 in Table 5 . The same monetary shocks move Zillow home values more dramatically than FHFA indices while consumption responses remain the same.

When taken together, results from the baseline model and robustness regressions indicate that homeowners have substantial non-durable spending responses to house price growth whereas renters see little or even negative response. Furthermore, I have provided tests for the relative importance of collateral and wealth effects in driving this relationship. Using the DSR and Home-Equity-Debt measures, I find that potentially constrained homeowners who use home-equity debt are responsible for the bulk of the response in spending, whereas unconstrained households have negligible spending responses to home value increases. This provides strong evidence that, though wealth effects may play a role, the collateral effect drives the relationship between consumption and home values. Given these results, I now turn back to understanding the importance of homeowner balance sheets in propagating monetary shocks.

5.2 Homeowner Balance Sheet Channel

The homeowner balance sheet channel is the effect of monetary policy on non-durable spending acting through changes in home equity. As discussed previously, a monetary loosening lowers the user cost of housing and raises real house prices. This raises consumption through the collateral and wealth effects discussed above. This channel acts in parallel with other channels of monetary policy such as increases in incomes or decreases in interest rates. Identification of the balance sheet channel separately is achieved through comparing house price and spending responses across housing supply elasticities.

The response of consumption and house prices to an h quarter lagged monetary shock η_{t-h} is given by (4.3) and (4.4) in Section 4. Updating these expressions using the housing supply elasticity measures z_i used for identification yields:

$$\frac{d\Delta c_{i,t+1}}{d\eta_{t-h}} = \beta_1 \frac{d\Delta q_{i,t+1}}{d\eta_{t-h}} + \beta_2(h) + \beta_3 \frac{d\Delta x_{i,t+1}}{d\eta_{t-h}} \tag{5.1}$$

$$\frac{d\Delta q_{i,t+1}}{d\eta_{t-h}} = \gamma_1(h) + \gamma_2(h) z_i + \gamma_3 \frac{d\Delta x_{i,t+1}}{d\eta_{t-h}} \tag{5.2}$$

As before, the homeowner balance sheet channel is captured in the first term of (5.1). This term combines the effect of monetary policy on house prices $\frac{d\Delta q_{i,t+1}}{d\eta_{t-h}}$ given in (5.2) and the effect of house prices on spending β_1. The total effect on spending acting through this channel is given by $\beta_1 \left(\gamma_1(h) + \gamma_2(h) z_i + \gamma_3 \frac{d\Delta x_{i,t+1}}{d\eta_{t-h}}\right)$. The role of β_1 in driving this channel is evident from this expression. Given the significant effects of house prices on consumption estimated above, there is strong evidence that the homeowner balance sheet channel is a non-negligible component of the spending response to monetary policy in any area where $\frac{d\Delta q_{i,t+1}}{d\eta_{t-h}} \neq 0$.

The second and third terms, $\beta_2(h) + \beta_3 \frac{\partial \Delta x_{it}}{\partial \eta_{t-h}}$, capture non-housing effects of monetary policy acting through interest rates, incomes, and general economic conditions affected by the shock. Since income variables are included in x, any effect monetary policy has on income appears through $\beta_3 \frac{\partial \Delta inc}{\partial \eta}$. I assume that age and family size are unaffected by the shock, so $\frac{\partial \Delta x}{\partial \eta} = 0$ for these variables. In addition, monetary policy may impact spending through channels not explicitly included in the specification. This is captured by the coefficient $\beta_2(L)$.

Results of the estimation are available in Figures 7, 8, and 9. Figure 7 plots the deviations of consumption from trend after 4, 8, 12, and 16 quarters after a shock depending on land availability and zoning regulations in the household's MSA. Homeowner spending follows a similar pattern to house price responses discussed previously. Spending responses peak after approximately 12 quarters and display larger movements in areas with low land availability and stricter zoning laws.

Geographic heterogeneity in the spending responses can be seen in the maps presented in Figures 8 and 9. Each map depicts the spending response response to a 1 standard deviation (71 basis point) shock to the Federal Funds rate at lags of 4, 8, 12, and 16 quarters respectively. Patterns generally follow those seen in maps of the elasticity measures in Figure 3. Coastal and mountain cities display larger spending responses since house prices rise more substantially in those areas compared to MSA's in the middle of the country. This also depicts a strong heterogeneity in responses across regions of the US.

6 Contributions to Literature

This paper builds on a several strands of the literature. First, it establishes an empirical link between monetary policy and house price dynamics. It then describes the effect of house price fluctuations on non-durable expenditures. Following aggregate shocks, regions with larger house price responses also display larger consumption responses. This is evidence that increases in housing wealth loosen collateral constraints allowing consumers to borrow and spend more than they would be able to otherwise. Secondly, this paper estimates the amplification of macroeconomic shocks through the housing balance sheet channel in inelastic regions. By exploiting geographic and regulatory heterogeneity across Metropolitan Statistical Areas (MSA's), I decompose the impulse response of consumption to monetary and credit shocks into a baseline contribution without collateral constraints and the amplification occurring due to house price changes. This decomposition provides evidence of the relative importance of balance sheets in the transmission of monetary and credit shocks as well as the heterogeneous responses across various MSA's.

The recent financial crisis has brought into focus the importance of agency costs and borrower balance sheets in the amplification of small macroeconomic shocks. This literature on so-called "financial accelerators" contains several models stemming from early work by Bernanke and Gertler (1989); Kiyotaki and Moore (1997); Carlstrom and Fuerst (1997). These models feature agency costs in borrower-lender relationships that cause borrowing contracts to be linked to the value of collateral on the borrower's balance sheet. Shocks that increase asset values amplify output responses by improving balance sheet quality and loosening collateral constraints on borrowers. While the majority of this literature on the "balance-sheet channel" focuses on firm balance sheets and investment decisions, notable exceptions include work by Iacoviello (2005) and Aoki et al. (2004) who extend the sticky-price DSGE model of Bernanke et al. (1999) to household collateral constraints tied to housing values. They show that the presence of home-equity borrowing causes an amplification of housing demand shocks, providing a theoretical foundation for a "homeowner balance-sheet channel". My work empirically identifies the magnitude of this channel by decomposing the contribution of monetary and credit shocks into their baseline and "balance sheet" components.

Identification of the "homeowner balance-sheet channel" follows in two steps. I first identify the response of house prices to monetary policy. I then identify elasticity of non-durable spending to changes in housing wealth. The first step has been analyzed in the housing economics literature. Early work by Poterba (1984) describes an asset-pricing approach to house price dynamics where fluctuations in user cost of housing cause varying dynamics in prices as housing stock adjusts over time. Recent work by Glaeser et al. (2008) and Kermani (2013) extend this model to a framework where local housing supply is allowed to vary across regions. Regions with more inelastic housing supply display larger fluctuations in house prices due to changes in the user cost of housing. This paper empirically identifies this effect. Using measures of housing supply elasticity developed by Saiz (2010) and Gyourko et al. (2008), I show that metropolitan areas with large amounts of available land and loose zoning regulations have little response to monetary shocks while areas with geographic or regulatory constraints to new construction see substantial movements in house prices.

The second step in identifying the homeowner balance sheet channel is to empirically establish the link between housing wealth and non-durable spending. This can occur for one of two main reasons: wealth effects or collateral effects. A pure wealth effect from an increase in home value to an infinitely lived household is likely small as implicit rental payments rise along with the asset value of the home. While life cycle effects may cause young home buyers or older home sellers to have wealth effects, spending responses are likely muted as households smooth the wealth fluctuations over their life cycle. On the other hand, collateral constraints may result in a substantial effect of housing assets on spending. This paper follows a long line of literature on household liquidity and borrowing constraints (Carroll and Dunn, 1997; Zeldes, 1989). The existing literature has established the importance of borrowing constraints in explaining violations of the Permanent Income Hypothesis, specifically excess sensitivity of consumption to current income for constrained households. Several authors have focused on the importance of housing assets in partially mitigating the effect of these constraints. Flavin and Yamashita (2002) and Flavin and Nakagawa (2008) discuss the effects of housing and mortgages on life-cycle consumption and portfolio decisions in the presence of collateral constraints and adjustment costs. One major finding is that optimal household portfolios often cause the collateral constraint to bind at certain points in the life-cycle. This prevalence of constrained households is a motivating factor for studying the amplification in interest rate responses that work through fluctuations in collateral values.

Work by Hurst and Stafford (2004) and Cooper (2009) study the propensity to consume out of housing wealth and the use of refinancing to smooth income fluctuations over the life-cycle. Cooper (2009) uses PSID consumption data to analyze how changes in the value of housing, stock market wealth, and other assets affect the consumption behavior of households. Related work by Case et al. (2005) and Campbell and Cocco (2007) attempt to separate the propensity to consume out of housing wealth into the collateral and wealth effect components. Hurst and Stafford (2004) look at refinancing decisions and post-refinancing consumption behavior in the PSID. This paper builds on the literature by exploiting regional differences in housing supply elasticity to more precisely identify the causal effect of changes in home values on homeowner consumption. Evidence for collateral effects is presented by comparing the responses of potentially credit-constrained and unconstrained households to a home equity increase. It further addresses regional heterogeneity in consumption growth after national level shocks.

Several recent papers have also utilized variation in MSA-level housing supply elasticity as a means to compare local markets based on exposure to home equity changes. Barlevy and Fisher (2010) study the variation in lending practices based on differences in expected house price growth across cities. They find inelastic-supply cities saw higher levels of interest only mortgage lending during the housing bubble period due to the anticipation of future house price growth. Recent work by Mian and Sufi (2011) analyzes collateralized home-equity borrowing and finds that the average homeowner borrowing increased with house price growth during the housing bubble. This provides strong evidence that many households are constrained by the quality of their balance sheets and may wish to increase spending as house prices rise. A related paper by Kermani (2013) provides a theoretical foundation for the different evolution of house prices, leverage, and consumption dynamics in different housing supply environments. While these papers provide evidence that household borrowing is linked to home equity fluctuations, only indirect empirical evidence is provided regarding consumption responses. Using self-reported consumption expenditures on various categories of spending from the Consumer Expenditures Survey (CES), this paper complements the existing results on household credit by providing an empirical link between interest rates, home equity fluctuations, and consumption expenditures over time. Furthermore, it establishes the prevalence of these relationships even prior to the mid-2000's when home equity based lending skyrocketed due to rapidly rising house prices.

7 Conclusions

This paper utilizes consumption expenditure micro-data and attempts to exploit regional heterogeneity in land availability and land-use regulations to address several related research questions. Regional heterogeneity in geography and regulation is shown to cause heterogeneity in the responses of MSA-level house price growth following a national shock to monetary policy. This heterogeneity in responses is interpreted as shifts in housing demand resulting in different local outcomes due to heterogeneity in local housing supply elasticities. Specifically, the most inelastic MSA's in the US display a 4% reduction in home values over 2-3 years after a 1 standard deviation monetary shock of 71 basis points. By comparison, the most elastic-supply cities display little house price response as new construction holds home values in check. This heterogeneity in local housing markets is then exploited to identify the amplification of monetary shocks arising through the "homeowner balance sheet channel".

The homeowner balance sheet channel arises as a monetary loosening raises house values which provide collateral and wealth to homeowners, hence increasing their consumption. While monetary policy may affect household spending or, more generally, the real economy in a number of ways, balance sheet amplification mechanisms play an important role in propagating small monetary shocks. Furthermore, heterogeneity in ownership and local housing markets causes heterogeneous responses to monetary shocks across households and regions.

Estimation of this channel relies crucially on identifying the consumption response to house price growth. Using heterogeneity in housing supply, consumption and house price responses to monetary shocks are compared between elastic and inelastic supply MSA's. MSA's such as Dallas with large amounts of land and loose zoning laws see little house price growth after the shock whereas land-constrained and tightly regulated housing markets such as San Francisco see large real house price responses. Under the assumption that housing supply elasticity measures have no direct impact on consumption, a homeowner balance sheet only exists in regions with inelastic housing supply since home values are constant in highly elastic-supply markets. Using an IV estimator, consumption responses are compared across cities with differing land availability and zoning regulations to identify the elasticity of consumption to home value changes. Baseline estimates indicate an average increase in spending of 6-9 cents for a $1 increase in home equity.

Housing provides homeowners with both asset wealth as well as collateral against which they may borrow to finance spending. Differentiating between these roles is useful for understanding the economic consequences of monetary and credit shocks, and, more generally, fluctuations in home values. As discussed in the paper, collateralized lending arises due to agency costs between borrowers and lenders resulting in a market failure. Collateral mitigates this market failure by allowing borrowers to commit to repayment. For example, a household expecting higher wages in the future cannot credibly promise to provide labor and hence will not be extended a loan. Collateral, such as housing, is used to secure financing and insure the lender in the event of default. Increasing home values provide constrained borrowers with necessary collateral to access credit they would otherwise be unable to get despite potentially having the capacity to repay at a later date. This is different from a wealth effect as wealth does not affect the ability to access credit directly. Secondly, a collateral constrained individual is much more likely to spend an additional dollar of collateral since she is unable to equalize marginal utilities of consumption across periods and wishes to consume more today. An unconstrained individual will only have a wealth increase which will be smoothed over the life-cycle. This difference causes the collateral effect to be a much larger and more important effect in amplifying and propagating shocks.

While a variety of metrics are used by banks to assess credit-worthiness, ratios that employ flows and expenditures are used to utilize the strengths of the Consumer Expenditure Survey's design. Because of this, the Debt-Service Ratio is used as the preferred measure of credit constraints. Households in the top 25% of the DSR distribution spend approximately 14 cents per $1 of home equity increase compared with unconstrained households who have negligible responses. Furthermore, households who extracted home equity in the past year are shown to have even larger responses, spending as much as 28 cents per $1 of home value increase. This provides some strong evidence that collateral effects are the primary driving force in explaining the propensity to consume out of housing wealth.

Given the evidence that home values affect household consumption and that national shocks to credit and money move home values, it is natural to see that housing markets are important in amplifying monetary shocks. Consumption responses are shown to vary substantially across housing supply elasticity measures and ownership rates across regions. Increasingly land constrained or tightly regulated MSA's see larger responses in consumption compared with more elastic housing supply cities. The total response of consumption arising due to the homeowner balance sheet channel is initially small, but the channel becomes increasingly important as house prices responses peak after 10-12 quarters.

Furthermore, substantial geographic heteregeneity is present in the responses of consumption. Coastal cities and those in the mountains see large responses in consumption while those in the Great Plains see smaller changes in spending. This is not to say that elastic-supply regions are unaffected by monetary policy. In fact, these regions see the largest responses in residential construction compared to coastal and mountainous regions. In addition, the heterogeneity of consumption and investment responses may have important implications for the allocation of resources across the country. Future work hopes to better understand the cross-sectional spillovers between elastic and inelastic-supply housing markets.

This paper establishes a clear link between monetary policy, house prices, and non-durable consumption behavior. It shows that monetary policy has heterogeneous impacts on non-durable expenditures through a homeowner balance sheet channel. In the process, it establishes patterns in the responses of home values to monetary shocks and provides a novel technique for identifying the propensity to consume out of housing wealth. Furthermore, it provides evidence for the importance of housing as collateral to constrained homeowners.

Appendix

A Empirical Model as Partial Wold Form of VAR

Consider the VAR for the vector of aggregate variables Y_t^{agg} augmented by a household-level observation Y_t^{hh}. The assumption that household variables do not affect monetary shocks is captured by the exclusion restriction in the VAR given by:

$$\begin{bmatrix} A_{11}(L) & 0 \\ A_{21}(L) & A_{22} \end{bmatrix} \begin{pmatrix} Y_t^{agg} \\ Y_{it}^{hh} \end{pmatrix} = \begin{bmatrix} B_{11} & 0 \\ B_{21} & B_{22} \end{bmatrix} \begin{pmatrix} e_t^{agg} \\ e_{it}^{hh} \end{pmatrix}$$

The triangular exclusion restriction that $A_{12}(L) = 0$ allows the top block of the VAR to be separated from the bottom. Put differently, local or household-level variables do not enter the national VAR except through aggregates present in Y_t^{agg}. Therefore, the monetary authority is assumed to respond only to aggregate information, not individual or local variation unexplained by national aggregates. This assumption is supported both by the absence of local or distributional information from the Green Book Forecasts and other documents used by the FOMC when setting policy. Furthermore, the mandate of the Federal Reserve indicates stability in national aggregates rather than individual local markets.

Taking the top block alone, the national VAR can be estimated separately using only national aggregate data. Under stability conditions and the identifying restrictions discussed in the paper, aggregate variables will have a Wold Form and can be written as a moving average of structural shocks e_t^{agg}:

$$Y_t^{agg} = A_{11}^{-1}(L)B_{11}e_t^{agg}$$

This allows the lower block of the VAR, corresponding to household-level variables, to be written as a function of household variables and a distributed lag of aggregate shocks:

$$A_{22}Y_t^{hh} = C_1(L)e_t^{agg} + C_2 e_{it}^{hh}$$

where $C_1(L) = A_{21}(L)A_{11}^{-1}(L)e_t^{agg} + B_{21}$ and $C_2 = B_{22}$. Given that structural monetary shocks η_t are identified using the recursive formulation, these shocks can be separated from both non-monetary national shocks in e_t^{agg} and local shocks e_{it}^{hh}. Denoting $\tilde{e}_{it}$ as a vector of non-monetary shocks, we get:

$$A_{22}Y_t^{hh} = C_{11}(L)\eta_t + C_{12}(L)\tilde{e}_{it}$$

Finally, the use of MSA house price indices allows for the exclusion of any household's consumption from the house price equation. Denoting monetary shocks as η_t, house prices in the MSA of household i as $q_{i,t}$, and household i's non-durable spending as $c_{i,t}$, the above equation yields:

$$\begin{aligned} \Delta c_{i,t+1} - \beta_1 \Delta q_{i,t+1} &= \beta_2(L)\eta_t + \beta_3 \Delta x_{i,t+1} + u_{i,t+1} \\ \Delta q_{i,t+1} &= \gamma(L)\eta_t + \gamma_3 \Delta x_{i,t+1} + v_{i,t+1} \end{aligned}$$

The error terms $u_{i,t+1}$ and $v_{i,t+1}$ capture unobserved national and local shocks in $\tilde{e}_{it}$. This raises two issues. First, since $\eta_t \perp e_t^{agg}, e_t^{hh}$ based on the identification of monetary shocks in the VAR, it follows that $\eta_t \perp u_{it}, v_{it}$. This allows for identification of causal effects of monetary policy conditional on Δq and Δx. Total effects of monetary policy must account for the effect of monetary policy on Δq and Δx explicitly. Second, $u_{i,t}$ and $v_{i,t}$ are correlated within period and over time. Identification of β_1 requires an instrument for Δq that is exogenous to $u_{i,t+1}$ as discussed in the body of the paper.

B Standard Error Correction for Generated Regressors

The full model is specified as:

$$\begin{aligned}
\theta(L)Y_t &= \eta_t \\
\Delta c_{i,t+1} &= \beta\Delta q_{i,t+1} + \gamma_1(L)\eta_t^{hd} + \gamma_2 x_{t+1} + u_{it+1} \\
\Delta q_{i,t+1} &= \delta_1 inelast_i + \delta_2(L)\left\{inelast_i * \eta_t^{hd}\right\} + \delta_3(L)\eta_t^{hd} + \delta_4 x_{t+1} + \varepsilon_{it+1}
\end{aligned}$$

Simplifying notation, combine terms to form the following system:

$$\begin{aligned}
\eta_t &= \eta(\theta, Y_t) \\
y_{it} &= X_{it}\alpha + u_{it} \\
X_{it} &= Z_{it}\delta + \varepsilon_{it}
\end{aligned}$$

where $y_{it} = \Delta c_{it}$, $X_{it} = \begin{bmatrix} \Delta q_{it} & \eta_{t-L} & x_{it} \end{bmatrix}$, and $Z_{it} = \begin{bmatrix} inelast_i & \{inelast_i * \eta_{t-L}\} & X_{it} \end{bmatrix}$. Furthermore, since $\eta = \eta(\theta, Y_t)$, define each variable as a function of θ: $X_{it} = g_1(\theta)$ and $Z_{it} = g_2(\theta)$. Let $\hat{X}$ and $\hat{Z}$ be defined as the variables evaluated at $\hat{\theta}$.

The variable of interest is α, and the goal is to derive correct standard errors for the plug-in 2SLS estimator for this variable.

Assumption 1: $\hat{\theta} \xrightarrow{p} \theta$ and $\sqrt{T}\left(\hat{\theta} - \theta\right) \xrightarrow{d} N\left(0, V_\theta\right)$ as $T \to \infty$ where $\hat{\theta}$ is the estimator for the SVAR parameters.

***Assumption 2*:** $\sqrt{\frac{N}{T}} \to k < \infty$where N is the total number of consumption observations and T is the length of the time series data used in the VAR. This is not unreasonable given sample sizes remain stable in the CE over time.

Assumption 3: $\eta(\theta, Y)$ is differentiable in θ such that $\sqrt{T}\left(\eta_t(\hat{\theta}) - \eta_t(\theta)\right) \xrightarrow{d} N\left(0, \nabla\eta(\theta)' V_\theta \nabla\eta(\theta)\right)$

Assumption 4: $\hat{Q}_{ZX} = \frac{1}{N}\hat{Z}'\hat{X} \xrightarrow{p} E[Z'X] = Q_{ZX}$ and $\hat{Q}_{ZZ} = \frac{1}{N}\hat{Z}'\hat{Z} \xrightarrow{p} E[Z'Z] = Q_{ZZ}$

Assumption 5: $\frac{1}{N}\nabla g_2(\theta)'u \xrightarrow{p} E\left[\nabla g_2(\theta)'u\right] = 0$

The 2SLS estimator for α using the estimate $\hat{\theta}$ is:

$$\begin{aligned}
\hat{\alpha} &= \left[\hat{X}'\hat{Z}\left(\hat{Z}'\hat{Z}\right)^{-1}\hat{Z}'\hat{X}\right]^{-1}\left[\hat{X}'\hat{Z}\left(\hat{Z}'\hat{Z}\right)^{-1}\hat{Z}'Y\right] \\
&= \alpha + \left[\hat{Q}'_{ZX}\hat{Q}^{-1}_{ZZ}\hat{Q}_{ZX}\right]^{-1}\hat{Q}'_{ZX}\hat{Q}^{-1}_{ZZ}\frac{1}{N}\sum_i\left(\hat{z}'_i(x_i - \hat{x}_i)\alpha + \hat{z}'_i u_i\right) \\
\sqrt{N}(\hat{\alpha} - \alpha) &= \left[\hat{Q}'_{ZX}\hat{Q}^{-1}_{ZZ}\hat{Q}_{ZX}\right]^{-1}\hat{Q}'_{ZX}\hat{Q}^{-1}_{ZZ}\frac{1}{\sqrt{N}}\sum_i\left(\underbrace{\hat{z}'_i(x_i - \hat{x}_i)\alpha}_{\text{Term 1}} + \underbrace{\hat{z}'_i u_i}_{\text{Term 2}}\right)
\end{aligned}$$

Term 1 : $\frac{1}{\sqrt{N}}\sum_i \hat{z}'_i(x_i - \hat{x}_i)\alpha$**...** Plugging in $X = g_1(\theta)$

$$\begin{aligned}
\frac{1}{\sqrt{N}}\sum_i \hat{z}_i{}'\left(f_i(\theta) - f_i(\hat{\theta})\right)\alpha &= \left(\frac{\sqrt{NT}}{\sqrt{NT}}\right)\frac{1}{\sqrt{N}}\sum_i(\alpha \otimes \hat{z}_i)'\left(f_i(\theta) - f_i(\hat{\theta})\right) \\
&= \frac{\sqrt{N}}{\sqrt{T}}\left[\frac{1}{N}\sum_i(\alpha \otimes \hat{z}_i)'\nabla f_i(\theta)\right]\sqrt{T}(\theta - \hat{\theta}) + o_p(1) \\
&= k\hat{G}\sqrt{T}(\theta - \hat{\theta}) + o_p(1)
\end{aligned}$$

The MLE for θ is such that $\frac{1}{T}\sum_t s(\hat{\theta}, Y_t) = 0$. Rearranging the Taylor expansion of this equation around θ (as in Murphy and Topel, 1985) gives...

$$\sqrt{T}(\theta - \hat{\theta}) = -\frac{1}{\sqrt{T}}\left[\frac{ds}{d\theta}(\theta, Y)\right]^{-1}\sum_t s(\theta, Y_t) + o_p(1)$$

Plugging this in above, you get...

$$\frac{1}{\sqrt{N}}\hat{Z}'\left(X-\hat{X}\right)\alpha = -k\hat{G}\left[\frac{ds}{d\theta}(\theta,Y_t)\right]^{-1}\frac{1}{\sqrt{T}}\sum_t s(\theta,Y_t)+o_p(1)$$
$$= -\hat{G}k\hat{H}^{-1}\frac{1}{\sqrt{T}}\sum_t s(\theta,Y_t)+o_p(1)$$
$$= -\hat{G}\frac{1}{\sqrt{N}}\sum \hat{r}_i(\theta)+o_p(1)$$

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Term 2 : $\frac{1}{\sqrt{N}}\sum_i \hat{z}_i' u_i = ...$

$$\frac{1}{\sqrt{N}}\sum_i \hat{z}_i' u_i = \frac{1}{\sqrt{N}}\sum_i g_i(\hat{\theta})' u_i$$
$$= \frac{1}{\sqrt{N}}\sum_i g_i(\theta)' u_i + \left(\frac{\sqrt{N}}{\sqrt{T}}\right)\left(\frac{1}{N}\sum \nabla g_i(\theta)' u_i\right)\sqrt{T}\left(\theta-\hat{\theta}\right)+o_p(1)$$
$$= \frac{1}{\sqrt{N}}\sum_i g_i(\theta)' u + O_p(1)o_p(1)O_p(1)+o_p(1)$$

by Assumption 5 above, the second term is also $o_p(1)$. This yields...

$$\frac{1}{\sqrt{N}}\hat{Z}'u = \frac{1}{\sqrt{N}}g_2(\theta)'u + o_p(1)$$

Combining all terms together, the estimator $\hat{\alpha}$ is given by ...

$$\sqrt{N}(\hat{\alpha}-\alpha) = \left[\hat{Q}_{ZX}'\hat{Q}_{ZZ}^{-1}\hat{Q}_{ZX}\right]^{-1}\hat{Q}_{ZX}'\hat{Q}_{ZZ}^{-1}\left(-\hat{G}k\hat{H}^{-1}\frac{1}{\sqrt{T}}\sum_t s(\theta,Y_t)+\frac{1}{\sqrt{N}}\sum_i g_2(\theta)' u_i\right)+o_p(1)$$
$$\xrightarrow{d} \mathcal{N}(0,\Omega)$$

[15] Simply summing $s(\theta, Y_{t_i})$ over i will give $\sum_i s(\theta, Y_{t_i}) = \sum_t ks(\theta, Y_{t_i})$ since each time t has k identical values $s(\theta, Y_t)$ associated with it, one for each $i \in \{i \text{ such that } t_i = t\}$. In practice, I can use $\frac{1}{\sqrt{N}}\sum_i s(\theta, Y_{t_i})$. Combining this with the Hessian matrix, define $\hat{r}_i(\theta) = \hat{H}^{-1}s(\theta, Y_{t_i})$.

where

$$\Omega = \left[Q'_{ZX} Q_{ZZ}^{-1} Q_{ZX}\right]^{-1} Q'_{ZX} Q_{ZZ}^{-1} M Q_{ZZ}^{-1} Q_{ZX} \left[Q'_{ZX} Q_{ZZ}^{-1} Q_{ZX}\right]$$

and

$$\begin{aligned} M &= E\left[(z_i' u_i - G r_i)(z_i' u_i - G r_i)'\right] \\ &= E\left[z' u u' z - z' u r' G' - G r u' z + G r r' G\right] \\ &= E[z' V z - z' u r' G' - G R u' z + G G'] \end{aligned}$$

C Figures/Tables

Figure 1: Local House Prices and Housing Starts for Select MSA's

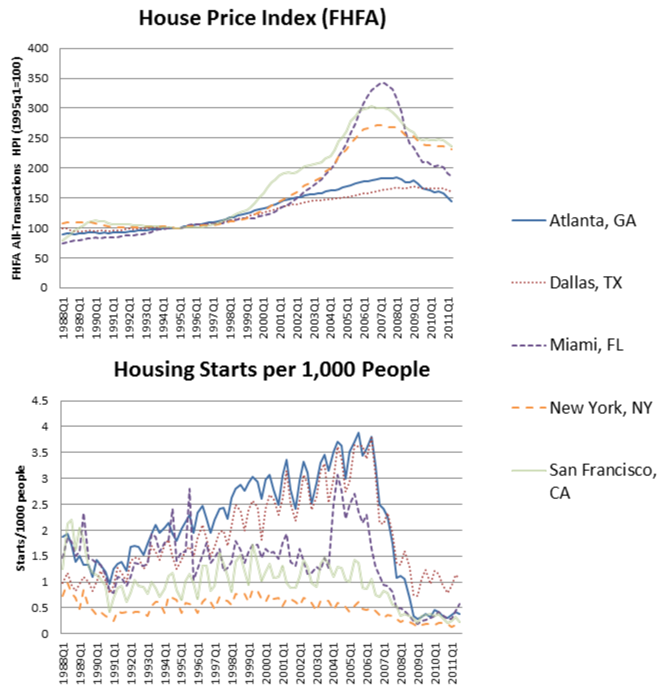

Figure 2: Housing Supply Elasticity vs House Price Growth

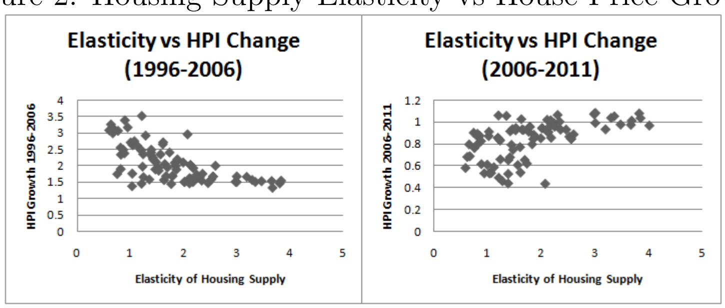

Figure 3: Housing Supply Elasticity Measures: Land Availability & Zoning Regulations

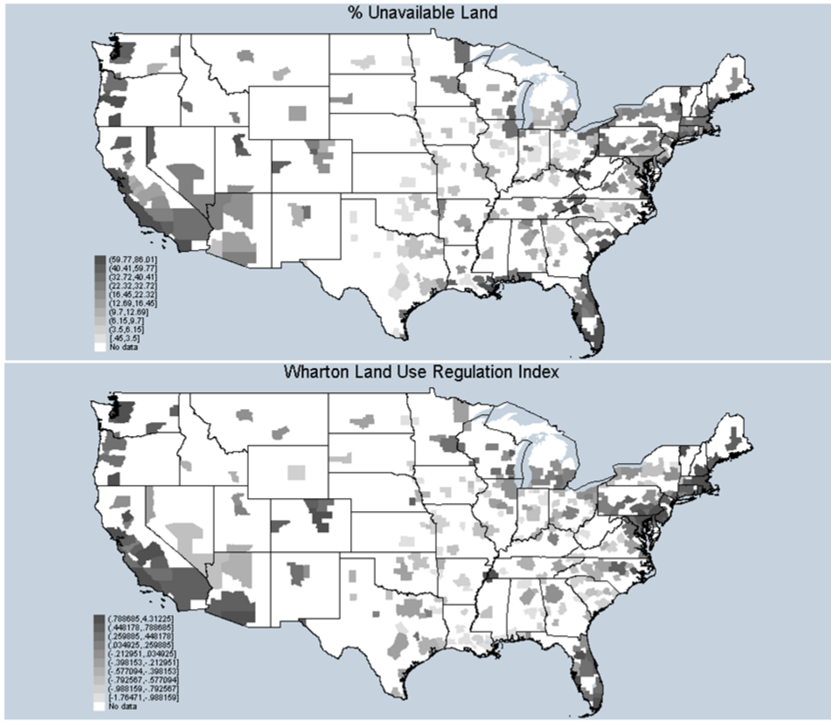

Figure 4: Comparison of National House Price Indices

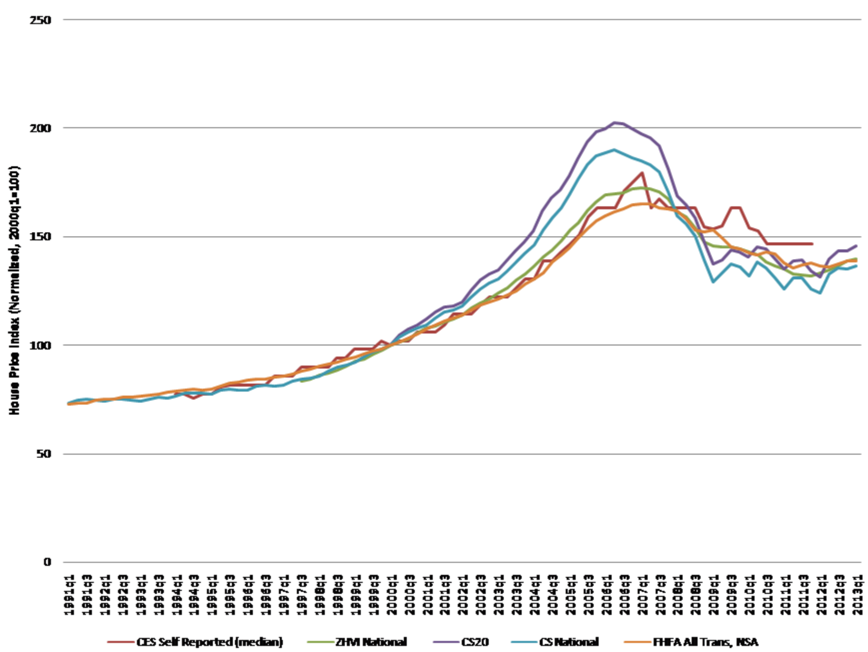

Figure 5: Time Series of Identified Monetary and Credit Shocks

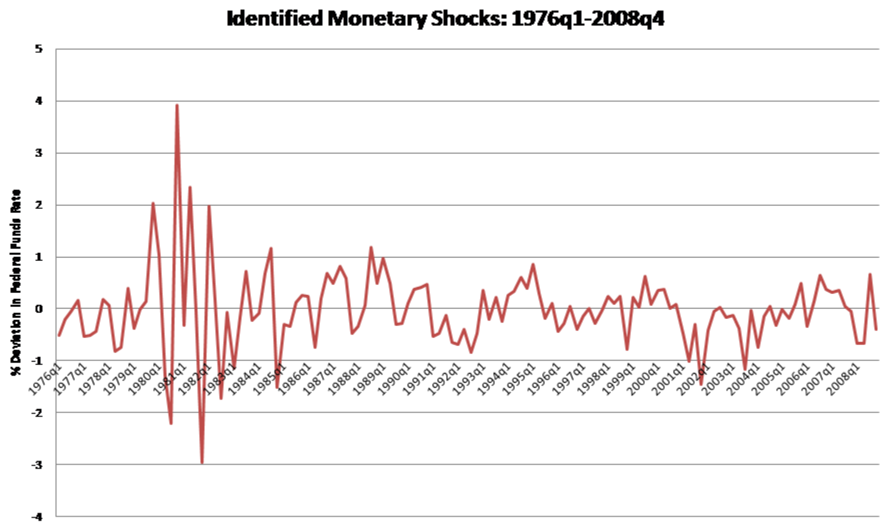

Figure 6: HPI Responses to 1sd Monetary Shock

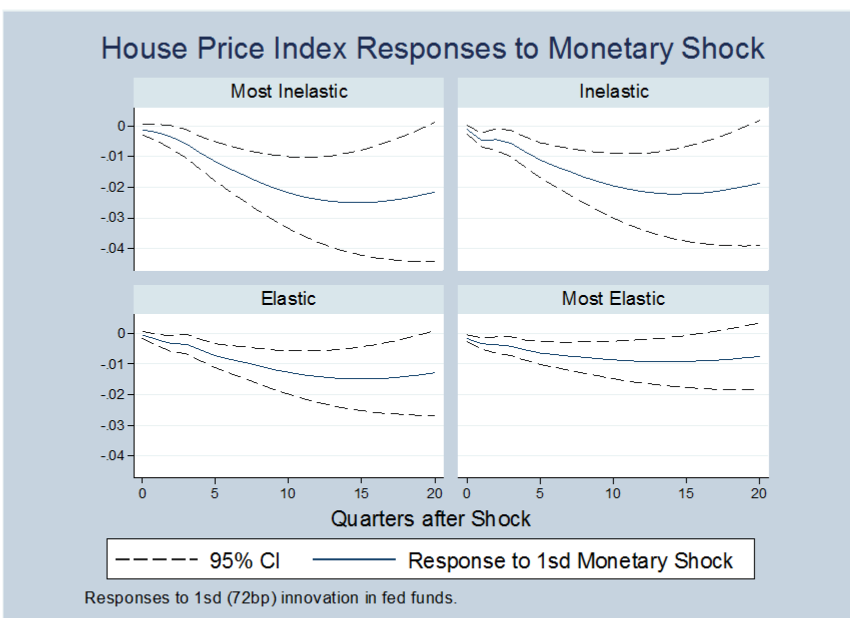

Figure 7: Spending Responses to 1sd Monetary Shock by Elasticity Measures

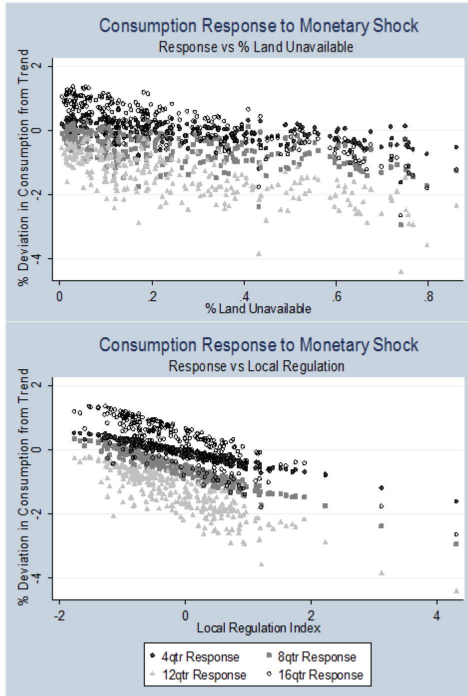

Figure 8: Map of Heterogeneous Spending Responses to 1sd Monetary Shock

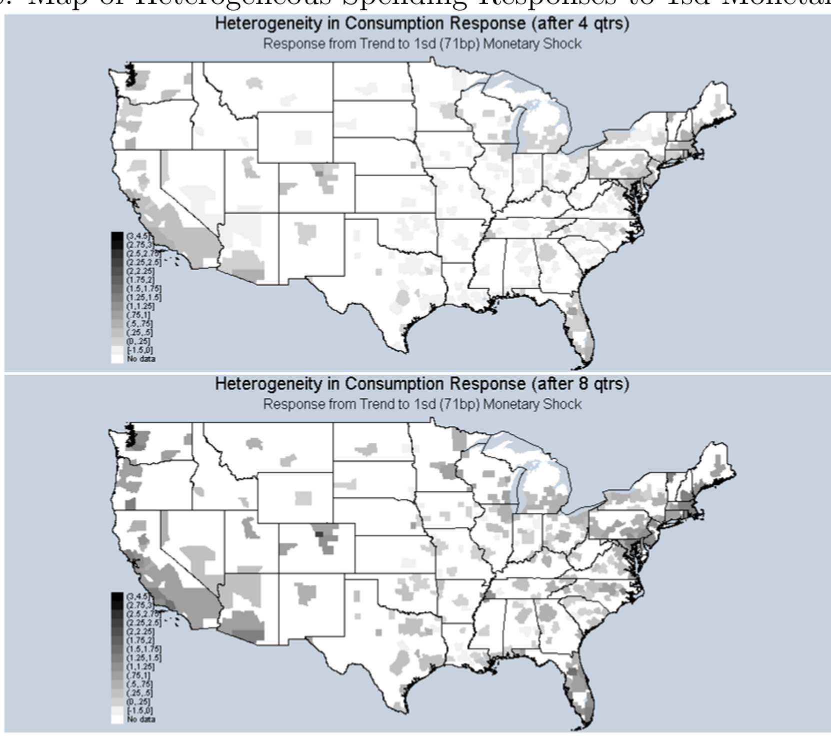

Figure 9: Map of Heterogeneous Spending Responses to 1sd Monetary Shock

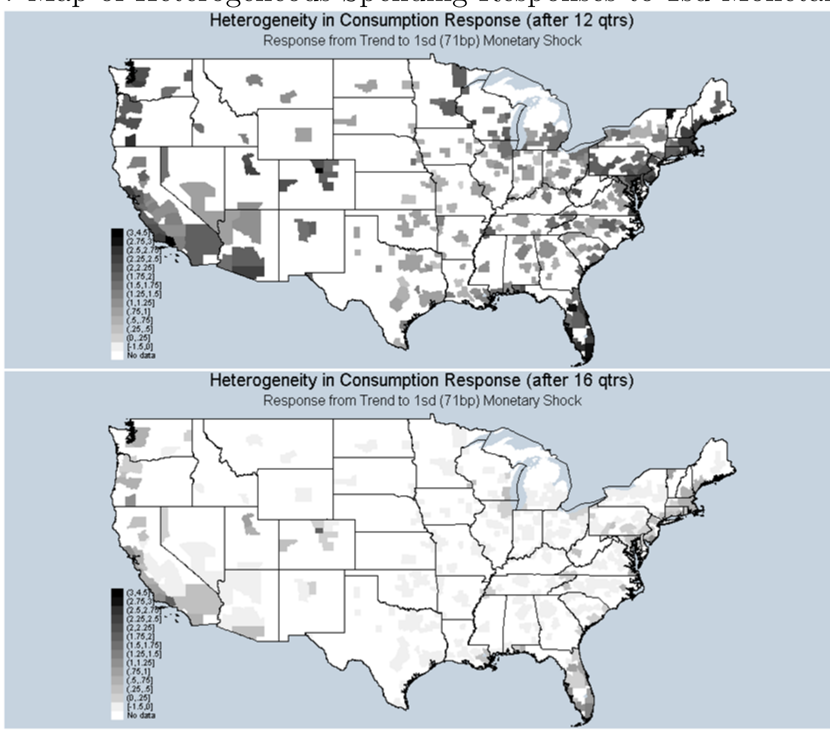

Table 1: Consumer Expenditure Survey Summary Statistics by Elasticity

	Lowest (33%) Elasticity	Middle (33%) Elasticity	Highest (33%) Elasticity	No Elasticity Data
Elasticity	0.8300	1.5439	2.9502	-
Mean Regulation Index	0.4590	0.4712	-0.3796	-
Mean % Unavailable Land	48.76%	25.40%	10.00%	-
% Owners	58.44%	67.45%	66.77%	71.06%
Age	47.96	46.83	46.96	46.17
Family Size	2.65	2.67	2.60	2.63
Home Value (Self-Reported)	$127,023.60	$227,781.50	$154,965.40	$104,095.10
Annualized Expenditures	$34,029.15	$40,096.96	$37,845.27	$34,761.22

Table 2: Land Availability, Regulation, and Supply Elasticity Measures of Select Large MSA's (Saiz, 2010)

MSA Name (Largest City)	Land-Use Regulation Index	Percentage Unavailable Land	Supply Elasticity Estimate (Saiz, 2010)	% Population less Elastic	MSA Population
St. Louis, MO-IL	-0.7286	11.08%	2.3558	76.54%	2,606,023
San Diego, CA	0.4628	63.41%	0.6728	8.65%	2,824,809
Minneapolis, MN	0.3777	19.23%	1.4474	47.37%	2,979,245
Phoenix AZ	0.6109	13.95%	1.6136	54.96%	3,276,392
Riverside, CA	0.5259	37.90%	0.9432	28.16%	3,280,236
Dallas, TX	-0.2287	9.16%	2.1753	69.46%	3,541,099
Atlanta, GA	0.0349	4.08%	2.5537	81.22%	4,144,774
Houston, TX	-0.3982	8.40%	2.3022	74.31%	4,199,526
Detroit, MI	0.0545	24.52%	1.2411	42.79%	4,444,693
Washington, DC	0.3105	13.95%	1.6058	53.38%	4,948,213
Philadelphia, PA	1.1267	10.16%	1.6451	58.70%	5,104,291
Boston, MA	1.7025	33.90%	0.8581	24.94%	6,067,510
Chicago, IL	0.0193	40.01%	0.8114	20.73%	8,289,936
New York, NY	0.6544	40.42%	0.7588	15.29%	9,321,820
Los Angeles, CA	0.4950	52.47%	0.6266	5.68%	9,546,597

Sources: Land-Use Regulation Index, unavailable land, and housing supply elasticity estimates from Saiz (2010). Population from 2000 Census for MSA.

Table 3: Consumption-Housing Elasticity Estimates - Baseline
Consumption Growth Regressions

	(1) Owners Only	(2) Owners w/ Mtg Rpt	(3) Renters Only	(4) All Households
House Price Growth	1.503***	1.077***	-0.00227	0.178
	(0.400)	(0.404)	(0.447)	(0.295)
Household Inc. Growth	0.0235***	0.0326***	0.0174***	0.0239***
	(0.00552)	(0.00635)	(0.00609)	(0.00456)
Local Inc. Growth	-0.0171	-0.224*	0.238*	0.139*
	(0.111)	(0.129)	(0.123)	(0.0798)
Age	-0.104**	-0.136**	0.0360	0.0163
	(0.0442)	(0.0598)	(0.0727)	(0.0425)
Age^2	0.00139***	0.00154**	0.000202	0.000231
	(0.000394)	(0.000622)	(0.000699)	(0.000400)
Chg. Family Size	9.932***	7.200***	6.655***	7.296***
	(0.896)	(0.998)	(0.929)	(0.709)
Observations	24,270	16,741	10,345	34,615

All regressions also include qtr. dummies & direct effects of monetary shocks.
Standard errors in parentheses are clustered at MSA-level.
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Consumption-Housing Elasticity Estimates - Collateral Constraints
Consumption Growth Regressions (Constrained vs Unconstrained)

	(1) Baseline Owners	(2) Constrained (high DSR)	(3) Unconstrained (low DSR)	(4) Increased Home Debt	(5) No Increase Home Debt
House Price Growth	1.503***	2.857***	-0.0655	3.569***	1.389***
	(0.400)	(1.028)	(0.495)	(1.203)	(0.374)
Household Inc. Growth	0.0235***	0.0516***	0.0188**	0.00943**	0.0544***
	(0.00552)	(0.0103)	(0.00845)	(0.00468)	(0.0111)
Local Inc. Growth	-0.0171	0.252	0.131	-0.592**	-0.123
	(0.111)	(0.310)	(0.0967)	(0.260)	(0.127)
Age	-0.104**	-0.900***	0.124**	-0.253*	0.0365
	(0.0442)	(0.139)	(0.0542)	(0.137)	(0.0632)
Age^2	0.00139***	0.00966***	-0.000607	0.00257*	0.000167
	(0.000394)	(0.00146)	(0.000488)	(0.00143)	(0.000603)
Chg. Family Size	9.932***	0.803	7.516***	10.63***	7.988***
	(0.896)	(1.893)	(1.120)	(1.570)	(1.108)
Observations	24,270	3,496	14,700	3,586	15,273

All regressions include qtr. dummies & direct effects of monetary shocks.
Standard errors in parentheses are clustered at MSA-level
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Consumption-Housing Elasticity Estimates - Select Robustness Checks

Consumption Response (Selected Robustness Checks)

	(1)	(2)	(3)	(4)	(5)
	Asset Returns	No Local Inc. Growth	Pre-tax Labor Inc.	Expected Inc. Growth	Zillow House Prices
House Price Growth	1.533***	1.070***	1.917***	0.756*	0.962***
	(0.401)	(0.387)	(0.351)	(0.406)	(0.160)
Household Inc. Growth	0.0245***	0.0294***		0.0316***	0.0463***
	(0.00555)	(0.00599)		(0.00630)	(0.00608)
Local Inc. Growth	0.00274		-0.122		
	(0.112)		(0.102)		
Pre-Tax Labor Inc. Growth			0.0601***		
			(0.00693)		
Exp. Local Inc. Growth				-0.0231	-0.149**
				(0.0799)	(0.0629)
10-yr Treasury Return	0.653***				
	(0.123)				
1year SP500 Return	-0.00984				
	(0.0173)				
Observations	24,270	27,979	18,711	24,320	12,864

All regressions include age, family changes, qtr. dummies & direct effects of monetary shocks.
Standard errors in parentheses are clustered at MSA-level
*** p<0.01, ** p<0.05, * p<0.1

References

K. Aoki, J. Proudman, and G. Vlieghe. House prices, consumption, and monetary policy: a financial accelerator approach. *Journal of Financial Intermediation*, 13(4):414 – 435, 2004. ISSN 1042-9573. doi: 10.1016/j.jfi.2004.06.003. URL http://www.sciencedirect.com/science/article/pii/S1042957304000282.

G. Barlevy and J. D. M. Fisher. Mortgage choices and housing speculation. Working Paper Series WP-2010-12, Federal Reserve Bank of Chicago, 2010. URL http://ideas.repec.org/p/fip/fedhwp/wp-2010-12.html.

B. Bernanke and M. Gertler. Agency costs, net worth, and business fluctuations. *The American Economic Review*, 79(1):pp. 14–31, 1989. ISSN 00028282. URL http://www.jstor.org/stable/1804770.

B. S. Bernanke and A. S. Blinder. The federal funds rate and the channels of monetary transmission. *The American Economic Review*, 82(4):pp. 901–921, 1992. ISSN 00028282. URL http://www.jstor.org/stable/2117350.

B. S. Bernanke, M. Gertler, and S. Gilchrist. The financial accelerator in a quantitative business cycle framework. *Handbook of Macroeconomics*, 1:1341–1393, October 1999. URL "http://ideas.repec.org/h/eee/macchp/1-21.html".

M. Bils and P. J. Klenow. Some evidence on the importance of sticky prices. *Journal of Political Economy*, 112(5):pp. 947–985, 2004. ISSN 00223808. URL http://www.jstor.org/stable/10.1086/422559.

J. Y. Campbell and J. F. Cocco. How do house prices affect consumption? evidence from micro data. *Journal of Monetary Economics*, 54(3):591 – 621, 2007. ISSN 0304-3932. doi: http://dx.doi.org/10.1016/j.jmoneco.2005.10.016. URL http://www.sciencedirect.com/science/article/pii/S0304393206001279.

C. T. Carlstrom and T. S. Fuerst. Agency costs, net worth, and business fluctuations: A computable general equilibrium analysis. *The American Economic Review*, 87(5):pp. 893–910, 1997. ISSN 00028282. URL http://www.jstor.org/stable/2951331.

C. Carroll and W. Dunn. Unemployment expectations, jumping (s,s) triggers, and household balance sheets. In *NBER Macroeconomics Annual 1997, Volume 12*, NBER Chapters, pages 165–230. National Bureau of Economic Research, Inc, 1997. URL http://ideas.repec.org/h/nbr/nberch/11039.html.

C. D. Carroll and M. S. Kimball. On the concavity of the consumption function. *Econometrica*, 64(4):pp. 981–992, 1996. ISSN 00129682. URL http://www.jstor.org/stable/2171853.

K. E. Case, J. M. Quigley, and R. J. Shiller. Comparing wealth effects: The stock market versus the housing market. Cowles Foundation Discussion Papers 1335, Cowles Foundation for Research in Economics, Yale University, 2005. URL http://EconPapers.repec.org/RePEc:cwl:cwldpp:1335.

L. J. Christiano, M. Eichenbaum, and C. L. Evans. Monetary policy shocks: What have we learned and to what end? Working Paper 6400, National Bureau of Economic Research, February 1999. URL http://www.nber.org/papers/w6400.

O. Coibion, Y. Gorodnichenko, L. Kueng, and J. Silvia. Innocent bystanders? monetary policy and inequality in the u.s. Working Paper 18170, National Bureau of Economic Research, June 2012. URL http://www.nber.org/papers/w18170.

D. Cooper. Impending spending bust? the role of housing wealth as borrowing collateral. *FRB Boston Public Policy Discussion Paper Series*, 09(9):1, 2009.

M. Flavin and S. Nakagawa. A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence. *The American Economic Review*, 98(1):pp. 474–495, 2008. ISSN 00028282. URL http://www.jstor.org/stable/29729980.

M. Flavin and T. Yamashita. Owner-occupied housing and the composition of the household portfolio. *The American Economic Review*, 92(1):pp. 345–362, 2002. ISSN 00028282. URL http://www.jstor.org/stable/3083338.

E. L. Glaeser, J. Gyourko, and A. Saiz. Housing supply and housing bubbles. Working Paper 14193, National Bureau of Economic Research, July 2008. URL http://www.nber.org/papers/w14193.

J. Gyourko, A. Saiz, and A. A. Summers. A new measure of the local regulatory environment for housing markets: Wharton residential land use regulatory index. *Urban Studies*, 45: 693–729, March 2008.

E. Hurst and F. Stafford. Home is where the equity is: Mortgage refinancing and household consumption. *Journal of Money, Credit and Banking*, 36(6):pp. 985–1014, 2004. ISSN 00222879. URL http://www.jstor.org/stable/3839098.

M. Iacoviello. House prices, borrowing constraints, and monetary policy in the business cycle. *The American Economic Review*, 95(3):pp. 739–764, 2005. ISSN 00028282. URL http://www.jstor.org/stable/4132738.

K. W. Johnson and G. Li. The debt-payment-to-income ratio as an indicator of borrowing constraints: Evidence from two household surveys. *Journal of Money, Credit and Banking*, 42(7):1373–1390, October 2010. URL http://ideas.repec.org/a/mcb/jmoncb/v42y2010i7p1373-1390.html.

A. Kermani. *Cheap Credit, Collateral and the Boom-Bust Cycle*. PhD thesis, Massachusetts Institute of Technology, 2013.

N. Kiyotaki and J. Moore. Credit cycles. *Journal of Political Economy*, 105(2):pp. 211–248, 1997. ISSN 00223808. URL http://www.jstor.org/stable/10.1086/262072.

P. J. Klenow and O. Kryvtsov. State-dependent or time-dependent pricing: Does it matter for recent u.s. inflation? *The Quarterly Journal of Economics*, 123(3):863–904, 2008.

doi: 10.1162/qjec.2008.123.3.863. URL http://qje.oxfordjournals.org/content/123/3/863.abstract.

A. Mian and A. Sufi. The consequences of mortgage credit expansion: Evidence from the u.s. mortgage default crisis. *The Quarterly Journal of Economics*, 124(4):1449–1496, 2009. doi: 10.1162/qjec.2009.124.4.1449. URL http://qje.oxfordjournals.org/content/124/4/1449.abstract.

A. Mian, K. Rao, and A. Sufi. Household balance sheets, consumption, and the economic slump*. *The Quarterly Journal of Economics*, 128(4):1687–1726, 2013. doi: 10.1093/qje/qjt020. URL http://qje.oxfordjournals.org/content/early/2013/09/20/qje.qjt020.abstract.

A. R. Mian and A. Sufi. House prices, home equity-based borrowing, and the u.s. household leverage crisis. *American Economic Review*, 101(15283):pp. 2132–2156, August 2011. URL http://www.nber.org/papers/w15283.

F. S. Mishkin. The channels of monetary transmission: Lessons for monetary policy. NBER Working Papers 5464, National Bureau of Economic Research, Inc, May 1996. URL http://ideas.repec.org/p/nbr/nberwo/5464.html.

K. M. Murphy and R. H. Topel. Estimation and inference in two-step econometric models. *Journal of Business & Economic Statistics*, 3(4):pp. 370–379, 1985. ISSN 07350015. URL http://www.jstor.org/stable/1391724.

A. Pagan. Econometric issues in the analysis of regressions with generated regressors. *International Economic Review*, 25(1):pp. 221–247, 1984. ISSN 00206598. URL http://www.jstor.org/stable/2648877.

J. M. Poterba. Tax subsidies to owner-occupied housing: An asset-market approach. *The Quarterly Journal of Economics*, 99(4):pp. 729–752, 1984. ISSN 00335533. URL http://www.jstor.org/stable/1883123.

A. Saiz. The geographic determinants of housing supply. *The Quarterly Journal of Economics*, 125(3):1253–1296, 2010. doi: 10.1162/qjec.2010.125.3.1253. URL `http://qje.oxfordjournals.org/content/125/3/1253.abstract`.

J. M. Wooldridge. *Econometric Analysis of Cross Section and Panel Data*. MIT Press, 2002.

S. P. Zeldes. Consumption and liquidity constraints: An empirical investigation. *Journal of Political Economy*, 97(2):pp. 305–346, 1989. ISSN 00223808. URL `http://www.jstor.org/stable/1831315`.