Same Shock, Separate Channels: House Prices and Firm Performance in the Great Recession

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Abstract

I explore whether credit supply conditions, working through local bank balance sheets, explain the influence of house prices on small businesses, both young and old, during the Great Recession. Combining confidential business-level microdata with housing and banking data, I show this credit supply channel substantially impacted old and small businesses. Young businesses, however, were more sensitive to house prices than old ones, but the bank credit channel explains little of their excess sensitivity. I then develop a macroeconomic model that is consistent with these findings where house prices work through two channels: a bank credit supply channel and a housing collateral channel.

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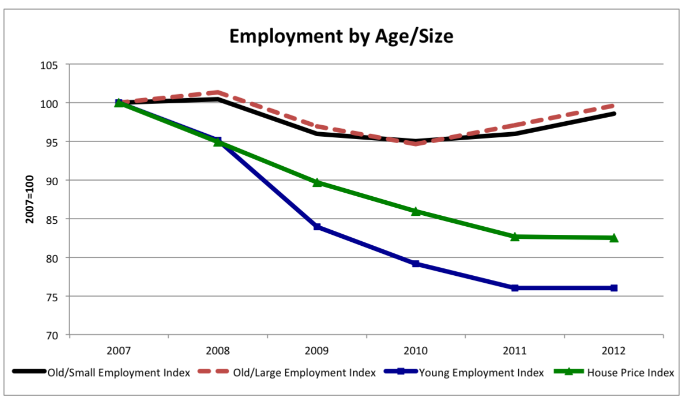
1 Introduction

House prices in the United States collapsed by almost 20 percent from the first quarter of 2007 to the second quarter of 2012. Concurrent with the housing collapse, the U.S. experienced the largest financial crisis and recession since the Great Depression, curtailing firms' ability to borrow (Ivashina and Scharfstein, 2010; Adrian et al., 2013; Santos, 2011). Figure one shows the recession fell disproportionately hard on young businesses (consistent with evidence from Fort et al., 2013), but the reasons for this disproportionate effect on are still largely undetermined (Davis and Haltiwanger, 2019). In this paper I explore the connection between house prices and credit supply conditions, and how they interact to affect firm employment. In both my empirical work and quantitative model, I find the effect of house prices working through credit supply channel varies by firm age, affecting old firms more than young.

Figure 1: Great Recession Employment by Age/Size



Source: Author Tabulations from BDS

My empirical work focuses the potential of local bank credit supply interacting with local house prices to explain the differences in firm outcomes over the Great Recession. Intuitively, local banks are particularly exposed to local housing market conditions through their balance sheets. As housing market conditions deteriorate, bank balance sheets also deteriorate, leading to less lending. For businesses that are reliant on local banks, this tightening in bank credit supply could lead to sharper reductions in real outcomes like employment. Several studies show business formation depends on local banking markets (Black and Strahan, 2002; Cetorelli and Strahan, 2005; and Kerr and Nanda, 2009), plausibly suggesting local banks local house prices and young firm performance. However, my results suggest local bank credit supply was not driving the asymmetric decline in young business employment during the Great Recession.

To capture this local bank credit supply channel, I combine publicly available data on banks from FDIC call reports and house prices from the FHFA with the Longitudinal Business Database (LBD) from the Census Bureau. I focus on house prices and their interaction with *pre*-crisis bank balance sheets, which proxy for bank "health" or "preparedness" prior to the crisis. Specifically, I exploit interactions of county-level house prices with pre-crisis bank balance sheet variables at the state level as either regressors or instruments in firm-level employment growth regressions. The interactions capture the extent to which local housing shocks are amplified or mitigated by banking conditions in the state, thus providing evidence of a local bank credit supply channel. **My focus is on how the effects of these proxies for local bank credit supply vary by firm age, but I also consider how effects vary by size.**

In each specification, I find meaningful effects of the credit supply channel on old businesses (at least 5 years old). However, I find that young businesses (less than 5 years old) are sensitive to local house prices, as in previous literature, but the local bank credit supply channel explains little of their performance over the recession. If we are to explain the disproportionate effect of house prices on young firm performance, then we need to look beyond the local bank. Further, the difference in the effect of local credit supply suggests mechanisms connecting house prices to firm performance are different for old vs. young firms.

My identification strategy relies on geographic segmentation–that businesses borrow from banks in their area. Survey evidence indicates this is

the case for small businesses (Petersen and Rajan (2002), Brevoort et al. (2009)), consistent with theoretical work on the acquisition of soft information (Boot and Thakor (1994), Agarwal and Hauswald (2010)). However, one would not expect large businesses to be as constrained to their local banks, and most would have access to broader financial markets. So, I also split old businesses between large (at least 500 employees) and small (less than 500 employees).[1] **I find that the results for old businesses are driven entirely by old/small businesses, and large businesses are generally not sensitive to local credit conditions.**[2] **These results attest are consistent with theory and, since general cyclical or demand conditions ought to affect large businesses as well, allay concerns that the local credit supply results are simply capturing common business conditions.**

This empirical evidence suggests that the housing crisis affected all businesses, but not in the same way or through the same channels. Crucially, these effects and channels vary by age. I construct a model that is consistent with these findings, capturing the importance of credit supply for older businesses and the disproportionate effect of house price shocks on young businesses. I propose a model with multiple channels through which house prices affect firms: a *credit supply* channel, which corresponds to the credit supply channel identified in my empirical work, and a *collateral channel*, which can be thought of as a credit demand channel. First, as identified in my empirical work, bank balance sheets interact with house prices to generate tighter credit conditions–an increase in interest rates and/or spreads–which in turn affects firms' ability to invest and hire. Second, I also incorporate a channel that limits credit demand through collateral values. This channel is modeled as a modified version of the standard collateral constraint, where housing

[1] Young businesses are overwhelmingly small, according to this definition, so I do not split them by size.

[2] This is not to say credit conditions did not matter for larger firms, as there is evidence that credit supply mattered greatly for them (e.g. Ivashina and Scharfstein, 2010; Adrian et al. 2013; Chodorow-Reich, 2014).

can be used as collateral for businesses (similar to Decker, 2015). If entrepreneurs use home equity as collateral for obtaining loans, then house prices can affect their ability to borrow by reducing collateral values.

The collateral channel is important for explaining the differential impact of a housing crisis on entrants and young firms in the model, while the credit supply channel is relatively important for old businesses. Intuitively, older firms are generally closer to scale and less constrained than young firms. Such firms respond more elastically to interest rate changes than constrained firms, whose responses are dampened by the constraint. Young firms tend to be constrained, with constraints either binding or close to binding, and thus are more sensitive to tightening in the constraint due to falling house prices. The credit supply channel has more bite in driving aggregate fluctuations through its impact on labor demand and capital accumulation, in particular for older firms who are more sensitive to interest rates. This leads to a more pronounced and persistent decline in economic activity when the credit supply channel is present. Still, the effect of the collateral channel on aggregate outcomes is substantial, and the interaction of the two channels generates an even more severe recession. For policymakers, the distinction of these two channels matters for the design of interventions. For example, policies that target credit markets may help older businesses more than young, while young businesses may be better served by more direct forms of support or general stimulus spending.

2 Related Literature

Several papers document the credit supply contraction during the Great Recession (e.g. Ivashina and Scharfstein, 2010 and Adrian et al., 2013). Much of this literature focuses on publicly traded firms, while I use data on near-universe of employer firms. Elsewhere, Cuñat et al. (2016) and Paixao (2017) investigate the role of housing markets for bank outcomes, as opposed to firm outcomes. Chodorow-Reich (2014) and Greenstone et al. (2020) document the impact of banking market variation for business outcomes, concurring on a large decline in credit supply but differing on the real effect on employment. Both papers focus on large lenders, whereas my focus will be on "local" banks which are more exposed to local house prices than large banks. Further, Greenstone et al. (2020) focuses on establishment outcomes, whereas I focus on firm age and size.

Prior literature documents the excess sensitivity of young firms to the cycle (Fort et al., 2014), and to house prices in particular (Davis and Haltiwanger, 2021). Further, previous literature has noted the excess sensitivity of small firms to financial conditions during the Great Recession (Chodorow-Reich, 2014; Siemer, 2019). My results are consistent with these previous findings. Generally speaking, it is young firms that are most sensitive to house prices, and smaller firms that are most sensitive to financial conditions.

Chodorow-Reich (2014), Siemer (2019), and Davis and Haltiwanger (2021) find excess sensitivity of young firms to financial conditions, in contrast to my findings. While differences in sample can explain the difference with Chodorow-Reich (2014) (the syndicated loan market is much restricted relative to the near universe of firms used here), the latter two papers have similar coverage with data based on the QCEW and BDS, respectively. Siemer (2019) finds that young firms in more externally dependent industries, based on Compustat data, were particularly affected during the Great Recession. Davis and Haltiwanger (2021) find that large national and regional bank credit supply was somewhat important for young firms, but less so than local house price variation. Both focus on broader financial market indicators, either industry-level or broader geographic footprints, that cannot account for the excess sensitivity of young businesses to *local* house prices. As Davis and Haltiwanger (2021) note, the influence of house prices on young firms beyond what can be captured by their credit supply shock instrument could be (in part) due to "local economic fortunes affect[ing] the lending capacity of local banks." My paper explores this hypothesis, but finds that local bank credit supply is more relevant for older firms.

One can thus reconcile the results from this paper with those of Davis and Haltiwanger (2021) and Siemer (2019) by noting the difference in focus for financial markets. It is possible that broader financial conditions, as captured by industry-level measures in Siemer (2019), and large national/regional bank credit supply, as captured in Davis and Haltiwanger (2021), are important factors for young businesses, while local banking markets are more important for older businesses that have developed relationships with local banks. There is significant heterogeneity in bank practices that can vary by size, notably that smaller banks are more engaged in relationship lending (Petersen, 2008). Thus, older businesses are likely the ones most affected by deterioration in local bank balance sheets. My findings suggest this is the case. Likewise, externally dependent firms might also rely more on collateral, which suggests the collateral effects incorporated into my model might capture some of the broader effects discussed in Siemer (2019). All told, financial conditions still matter for young businesses (consistent with my quantitative model), but the transmission of house prices through local banks does not seem to be a primary driver of their excess sensitivity to house prices.

Evidence for the collateral mechanism includes Lastrapes et al. (2022) and Kerr et al. (2022), who explore the importance of housing collateral for entrepreneurship and small businesses, generally finding modest but potentially lasting effects. The evidence provided in this paper on relevant local bank credit supply channel supports the evidence for credit supply channels in the literature. Taken together with the evidence for a housing collateral channel, this evidence supports the assumptions of quantitative model I construct to investigate the role of business formation and young firm growth in a financial crisis like the Great Recession.

My focus on firm age is grounded in the relative importance of young businesses for growth and their sensitivity to business cycles. Young firms contribute disproportionately to job creation (Haltiwanger et al., 2013). Evidence from the Great Recession suggests that young firms were among the hardest hit by the downturn and local house prices had a disproportionate impact on young firms (Fort et al., 2013; Davis and Haltiwanger, 2019). Further, aggregate conditions exhibit persistent influence over young firms, with business cycle conditions persisting for cohorts of young firms long after aggregate employment has recovered (Sedlàček and Sterk, 2017). While there are several promising channels for the disproportionate impact of house prices on young businesses, there is little evidence documenting the relative importance of such mechanisms. On the other hand, old businesses make up the vast majority of employment. Calculations based on the Business Dynamics Statistics (BDS) show that in 2007 old/small businesses (at least five years old and less than 500 employees) accounted for about 38 percent of employment, while young businesses comprised 14 percent of total employment. Old/large businesses then make up about half of employment in the U.S. Thus, shocks that impact old businesses could potentially impact aggregate outcomes more than those that impact young businesses, while shocks to young businesses that persist might impact medium to long-run growth prospects.

This paper builds on much theoretical and quantitative work exploring the effects of financial frictions. These models often feature collateral constraints that fall directly on firms (e.g. Kiyotaki and Moore, 1997; Cooley et al., 2004). I incorporate housing as collateral, similar to Decker (2015). Other models focus on the role of the financial sector in generating financial distress via interest rate (consistent with evidence from Santos, 2011; and Gilchrist and Zakrajšek, 2012), rather than a collateral constraint shock. Several papers consider exogenous "spread shocks" where intermediation costs rise mechanically, including Chodorow-Reich (2014) and Ajello (2016). My paper closely follows Gertler and Kiyotaki (2015) by imposing an internal incentive constraint on banks. Rather than expose banks to capital quality or productivity shocks through equity claims on capital, in this paper banks have housing equity on their balance sheets. This connects the financial crisis to housing, generating an endogenous tightening in credit conditions in response to house prices declines, which are in turn a result of a change in housing preferences.

In section 2, I present empirical results on the effects of local house prices and local bank credit supply on firm outcomes. I detail the model in section 3 before discussing calibration, results, and counterfactuals in sections 4 and 5.

3 Empirical Analysis

I now turn to my strategy for identifying a channel through which house prices affect financial conditions faced by businesses. Davis and Haltiwanger (2019) highlight the importance of local house prices for young firm employment, and I begin by corroborating this finding. Further, I seek to disentangle channels hypothesized in previous literature. In particular, I seek to identify whether *local* house price changes influence *local* businesses through *local* banks. The goal is to determine whether the outsize effect of house prices on young businesses can be accounted for by local banking conditions. At the heart of the strategy are interactions of annual house prices changes with *pre-crisis* indicators of bank balance sheets. By focusing on balance sheets prior to the crisis, I am relying on an assumption that bank balance sheet structure, and bank health in general, prior to 2007 did not anticipate the subsequent declines in housing prices over the Great Recession. Additionally, there must be disproportionate exposure of local banks to local house prices, and that exposure has a significant impact on bank health. If these assumptions hold, local house prices impact banks, in turn restricting their lending. Then, the interaction of house prices with the pre-crisis bank balance sheets would serve as a proxy for changes in local bank credit supply. I discuss the data used to implement this approach before turning to a discussion of identification challenges and broader applicability.

3.1 Data

I combine data in the Longitudinal Business Database (LBD) from the US Census Bureau with public data on bank balance sheets from FDIC call reports, house price data from FHFA, and unemployment data from the BLS. For the vast majority of firms in the US economy, financial data is difficult to obtain. Most datasets cover large and publicly traded firms, and even then little is known about lenders or lending relationships.[3] The advantage of this paper is its coverage of the US economy, but I ultimately must rely on geographic matching with banking data to characterize the lending environment of the firm, which assumes lending markets are to some degree geographically segmented. Survey evidence indicates small businesses borrow from nearby banks (Petersen and Rajan (2002), Brevoort et al. (2009)), consistent with theoretical work on the acquisition of soft information (Boot and Thakor (1994), Agarwal and Hauswald (2010)). Further, the evidence of banking relationships during expansions and recessions (Petersen and Rajan (1994), Chodorow-Reich (2014)), suggest that such segmentation is important. My results corroborate this view.

The LBD is an annual dataset derived from administrative records that covers the near-universe of establishments in the US economy. The dataset includes a measure of employees as of March 12 of the year and annual revenue. Furthermore, the dataset contains data on location, industry, multi-unit status, and age.[4] I focus on employment growth at the local level within a firm. That is, the unit of observation in each specification is a firm's establishments within a county and industry. In essence, this is a modified notion of establishment where individual establishments are aggregated if they share an owner, industry, and county. This allows me to focus on the response of the firm to local shocks impacting its establishments, without overweighting firms with multiple establishments in a county/industry bin. To simplify exposition, I will refer to the unit of observation as an establishment.[5] I explore heterogeneity by running regressions by groups: young, old, old/small, and old/large. The definitions

[3] Dinlersöz et al. (2017) uses the ORBIS dataset to cover a larger portion of small and young firms. See Chodorow-Reich (2014) for research documenting banking relationships among generally large firms borrowing in the syndicated loan market.

[4] Further detail on the data construction process for the LBD, including cleaning, can be found in the data appendix of Haltiwanger et al. (2016).

[5] The March-to-March timing of the LBD poses some difficulty in aligning house price and unemployment data with the outcome data. I choose concurrent years for HPI and quarter 2 unemployment in my main regressions. I discuss the merits of this choice and explore alternative timing assumptions in the appendix. Most results carry through, although the influence of house prices on young businesses vs. old/small businesses is not as stark.

used are as in figure 1: age and size are defined at the firm level and assigned to all establishments that make up the firm regardless of location or industry.

To develop a measure of financial conditions in the local market of the establishment, I use data from the FDIC call report database. These data cover all insured institutions in the United States, providing detailed information on assets, liabilities, ownership structure, locations, and ownership history. I take annual averages of these quarterly data to create an annual dataset. I roll up banks to the ownership level, or bank holding company level. To make these data consistent with the theory of financial market segmentation mentioned above, I restrict to banks that only have branches in one state and bank holding companies that only have one bank that has branches in one state.

These banks are as small as several million dollars in assets up to large community banks of well over a billion dollars. Figure 2 provides an example of the relative importance of these banks, as they have accounted for roughly 10% of business loans in the 2000s, but over 30% of small business loans. Given the theoretical background of financial market segmentation, small business lending is likely the more important function.[6]

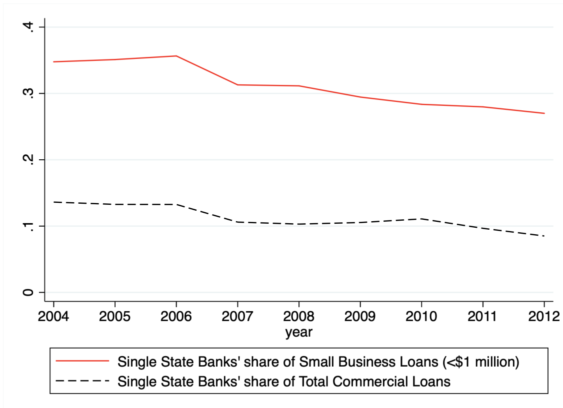
I then roll each of the variables of interest up to the state level, creating a representative "state bank balance sheet" to characterize the variation in bank balance sheet structure across states. I obtain house price data from the FHFA at the county level and unemployment at the county and state level from the BLS. I begin my sample in 2008, at the onset of the recession, and since my focus is on house prices, which continued to decline until the second quarter of 2012, I end my sample in 2012.[7] I use year-over-year changes in either the second quarter or June, depending on frequency,

[6] I clean the data further, removing large banks, such as credit card companies, that only have one reported branch, but are obviously not local state banks. Due to the small number of state banks in Delaware, the District of Columbia, and New Hampshire, I merge these states with Pennsylvania, Maryland, and Vermont, respectively.

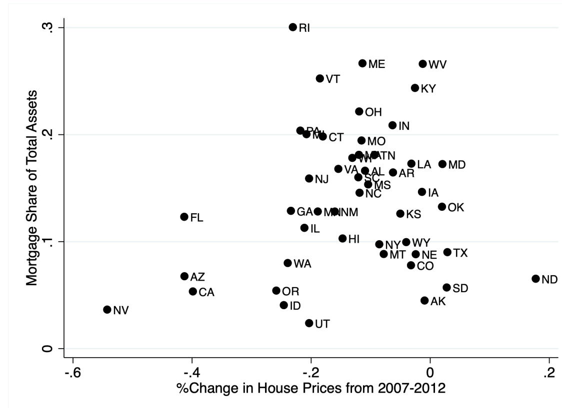
[7] Additionally, bank exits, a key variable in my analysis, rose sharply beginning in 2008 and continued at an elevated pace until at least 2012 as well.

Figure 2: Single-State Banks and Single-Bank/Single-State BHC's Share of Lending and House Prices

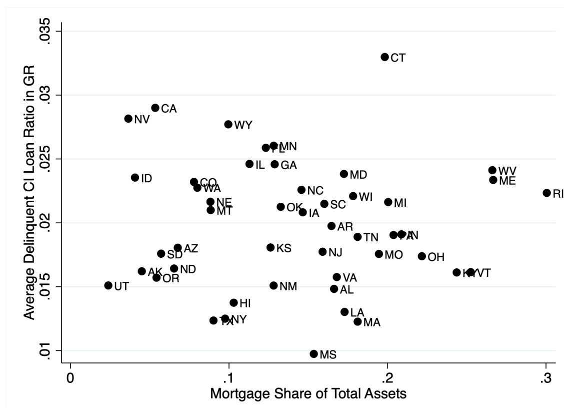
(a) Lending Share (percent of total valuation)



(b) Mortgage Share and House Price Changes



(c) Pre-crisis Mortgage Share and Subsequent Delinquency Rates for Commercial Loans



Author's Calculations from the FDIC Call Report Data and FHFA. Mortgage Shares are calculated as an average of all single-state banks in 2005. Delinquency rates are calculated as the average annual delinquency ratio of delinquent commercial loans (noncurrent and 90 days past due) to total commercial loans in a state during the years 2007-2012.

for each series.

3.2 Empirical Framework

To establish continuity with previous literature, I run a simple regression of the establishment $e's$ employment growth $\Delta Y_{e,t}$ as calculated in Davis et al. (1996), henceforth DHS growth rates, from time $t-1$ to t on the log change in county c

house prices $\Delta HPI_{c,t}$ from $t-1$ to t:[8]

$$\Delta Y_{e,t} = \gamma_1 \Delta UR_{c,t} + \gamma_2 \Delta UR_{s,t} + \beta_{\mathbf{1}} \mathbf{\Delta HPI_{c,t}} + \alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t} \qquad (1)$$

I include time effects δ_t, county fixed effects α_c, and changes in county unemployment rates $\Delta UR_{c,t}$. I also include detailed (6-digit NAICS) industry fixed effects τ_i and the log of the denominator of the DHS growth rate as a size control. Since I consider broader implications of state bank balance sheets, I include an indicator of state unemployment rate changes $\Delta UR_{s,t}$. I cluster at the county level. Due to the apparent nonlinearities in age and size, as stressed by Fort et al. (2013) and Dinlersöz et al. (2017), the results are broken out by four firm categories: young (less than 5 years old), old (5 years or older), old/small (at least 5 years old and less than 500 employees), and old/large (at least 500 employees), where age and size are defined at the firm level.[9]

House prices are clearly endogenous, so I implement a common instrumental variable approach using the housing supply elasticities from Saiz (2010). To begin, I estimate the following first stage:

$$\Delta HPI_{c,t} = \Gamma_1 \Delta UR_{c,t} + \Gamma_2 \Delta UR_{s,t} + \beta_2 \Delta UR_{c,t} * \eta_{m,t} + a_c + d_t + T_i + \varepsilon_{c,t} \qquad (2)$$

Where $\eta_{m,t}$ is a metro-level measure of housing supply elasticities as in Saiz (2010). The identification assumption here is that predicted house price changes $\widehat{\Delta HPI}_{c,t} = \widehat{\beta}_2 \Delta UR_{s,t} * \eta_{m,t}$ are orthogonal to the error term in the second stage: $\epsilon_{e,t}$. These predicted house price changes are then the (plausibly exogenous) explanatory variables in the first stage (equation 1).

[8]Note this measure is inclusive of entry and exit, and is calculated as the change in employment over the average of employment in the two periods. Formally, $\Delta Y_t = \frac{Y_t - Y_{t-1}}{(Y_t + Y_{t-1})/2}$. I use the denominator as the control for size in the regressions in this paper.

[9]Specifications with interactions of fixed effects are available upon request. Likewise, alternative specifications with fully interacted dummies for age/size rather than separate regressions by age/size are available.

I then run a specification which captures the impact of house prices on firms through credit supply of banks due to the shape of their bank balance sheet. I follow Cole et al. (2012), who show the predictive power of a set of bank balance sheet ratios on bank failure during this period, in my selection of bank variables. By focusing on a single snapshot of bank balance sheets in 2005, I extend the spirit of this line of reasoning to investigate the impact of pre-crisis bank preparedness, and thus their tendency to adjust credit supply in response to house price shocks, on real outcomes. I consider two primary approaches. First, I use a simple framework where I directly include the interaction between house prices and the mortgage share of bank balance sheets in a firm growth regression. This approach is easily interpretable and theoretically consistent with a model of deteriorating asset values induced by a decline in house prices. This specification is identical to the previous specification, but with the addition of an interaction between house prices and the share of mortgages on state bank balance sheets that aims to capture the effect of house prices working through a credit supply channel among local banks:

$$\Delta Y_{e,t} = \gamma_1 \Delta UR_{c,t} + \gamma_2 \Delta UR_{s,t} + \beta_{\mathbf{1}} \mathbf{\Delta HPI_{c,t}} + \beta_{\mathbf{2}} \mathbf{\Delta HPI_{c,t}} * \mathbf{MTG_{s,2005}} \qquad (3)$$

$$+\alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t}$$

Again, I instrument for house prices as before, and further instrument the interaction of house prices and mortgage shares with interactions between housing price elasticities, state unemployment rate changes, and the mortgage share. However, this time I include interactions with the quadratic and cubic of the change in state unemployment, as the first stage is underidentified in the linear case. My first stage thus consists of house prices and their interaction with pre-crisis mortgage share as endogenous variables regressed on the following instruments: (log) elasticity of county house prices η_m , the quadratic η_m^2, and the cubic term η_m^3 interacted with $\triangle UR_{s,t}$, as well as the interaction of η_m with $\triangle UR_{s,t}$ and the standardized (normalized to mean 0 standard deviation 1) mortgage share $MTG_{s,2005}$, η_m^2 interacted with $\triangle UR_{s,t}$ and $MTG_{s,2005}$, and η_m^3 interacted with $\triangle UR_{s,t}$ and $MTG_{s,2005}$.

Second, I consider a two-stage setup where bank health is proxied by bank exit. Bank health is a complicated multi-dimensional object, so it is difficult to develop a "bank health" index. However, I can observe bank exit over the period I am investigating. Since bank exit is endogenous to firm performance, I develop a predictive model of bank exit in my first stage with pre-crisis bank balance sheet variables interacted with house prices on the right hand side.[10] In a sense, predicted bank exit acts as an index for the interaction of house prices with bank balance sheets. Specifically I include as a regressor the exit rate of banks weighted by total assets $BE_{s,t}$ in the state s in which county c is located, either by failure or acquisition:[11]

$$\Delta Y_{e,t} = \gamma_1 \Delta UR_{c,t} + \gamma_2 \Delta UR_{c,t} + \beta_{\mathbf{1}} \mathbf{\Delta HPI_{c,t}} + \beta_{\mathbf{3}} \mathbf{BE_{s,t}} + \alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t} \quad (4)$$

As before, I run this regression separately by age and size. The first stage for an instrumental variable approach is then given by:

$$BE_{s,t} = \Gamma_1 \Delta UR_{s,t} + \sum_j \zeta_j \Delta HPI_{s,t} * BBS_{j,s,2005} + a_s + d_t + \varepsilon_{s,t} \quad (5)$$

Here, each bank balance sheet variable $BBS_{j,s,2005}$ listed in the appendix is normalized to mean zero in 2005. The identifying assumption is that $\widehat{BE}_{s,t} = \widehat{\zeta}_j \Delta HPI_{s,t} * BBS_{j,s,2005}$ is orthogonal to the disturbances in the second stage equation. I employ the same state unemployment housing supply elasticity instruments as before, along with interactions with balance sheet variables, to isolate plausibly exogenous house price growth interacting with balance sheet variables to predict bank exit $BE_{s,t}$.

[10] I follow Cole and White (2012) in my choice of balance sheet variables, which include asset ratios, liability/asset ratios, and profitability measures (see appendix).

[11] While failure is a clear sign of distress, and exit in normal times is not necessarily a sign of distress, it is reasonable to assume the tremendous increases in both failures and exits are likely due to distress given the financial environment in the time frame considered.

3.2.1 Identification and External Validity

They key challenges to my identification strategy are the endogeneity of house prices and the validity of pre-crisis bank balance sheets as a proxy for bank health that is independent of other factors related to firm performance in the Great Recession. To address house price endogeneity, I use a standard approach to isolate plausibly exogenous residual changes in house prices due to variation in housing supply elasticities as in Saiz (2010). Previous literature has criticized this instrument due to its correlation with industry structure. My approach uses establishment level data to sweep out detailed (6-digit NAICS) industry effects to mitigate this concern.[12] I generally follow Davis and Haltiwanger (2019) in interacting housing supply elasticities with local economic indicators. This approach requires that predicted house price growth from local unemployment changes interacted with housing supply elasticities in the first stage are uncorrelated with the error term in the second stage. In subsequent regressions, whenever house prices are interacted with pre-crisis bank balance sheets in OLS regressions, IV specifications likewise use similar interactions in the first stage.[13]

The second concern is that pre-crisis bank balance sheets are correlated with other determinants of employment outcomes during the crisis. In figure 2, I provide some suggestive evidence that this does not appear to be the case. First, one might be concerned that pre-crisis mortgage shares are correlated with "bubbly" housing markets: those states with high mortgage shares are those with the largest runup and subsequent fall in house prices. Figure 2 (b) shows this is not the case. House price declines in the 2007-2012 period are not significantly correlated with the pre-crisis mortgage share. Second, one might be concerned that states with banks that held a large share of mortgages might generally make poor lending decisions. In that case, banks with high mortgage shares might also tend to experience higher default and delinquency

[12] Guren et al. (2021) propose an alternative instrument, which yields similar elasticities to Saiz (2010).

[13] Note that the Saiz (2010) elasticities are only available for counties in metro areas. In light of this, I report both regressions with house price changes to maintain complete geographic coverage and instrumented house price changes to plausibly claim exogeneity.

rates on *commercial* loans during the Great Recession. Figure 2(c) demonstrates that average state delinquency rates over the Great Recession are uncorrelated with mortgage shares among banks in my sample, suggesting that banks engaged in higher lending activity were not generally experiencing higher delinquency.[14]

A related concern for the mortgage approach is that many banks were engaged in securitization. The mortgage variable here is individual single-family mortgage held on bank balance sheets, not packaged security products of multiple mortgages. It is possible banks with individual mortgages planned to sell them. An assumption that these banks were not involved in securitization is not necessary, and would be too strong. A sufficient identifying assumption is that banks maintained similar shares of individual mortgages *that were disproportionately exposed to local house prices* between 2005 and the onset of the recession. This is possible if the banks are replacing mortgages sold with newly issued mortgages, for example.

Another concern is that the young/old distinction is driven by differential demand. I show in the appendix the results of similar regressions for the tradable sector defined in Mian and Sufi (2014). I find that house prices have a similar impact on young firms even in this sector, consistent with evidence in Davis and Haltiwanger (2019). Furthermore the bank credit supply channel has a similar effect in this sector in some specifications, specifically the bank exit approach.

Finally, macroeconomists might be concerned with the broader applicability of these findings for large banks, which my identification strategy exclude. In the appendix, I present results of bank-level exit (rather than state-wide exit rates as in the main analysis) and lending outcomes regressed on house prices and mortgage share interactions with house prices. In these auxiliary regressions, house prices are constructed by using FDIC bank-branch level data on deposits to construct bank-specific housing prices. The resulting analysis yields mixed results which nonetheless suggest the mechanisms explored in this paper are similar for larger banks. Multi-state banks

[14]Similarly, Cole and White (2012) generally find mortgages to be negatively associated with bank failure, suggesting that it is not a measure that typically captures poor bank management.

are impacted by local house prices via the exit margin, although necessarily through mortgage delinquencies. There is not much evidence for lower commercial lending due to house price exposure among multi-state banks, although directionally coefficients suggest similar mechanisms to single-state banks.

3.3 Results

In what follows, I establish the correlation between housing values and firm performance briefly before discussing the alternatives for identifying a local credit channel. In each table, I present results by young, old, old/small, and large, and in some cases I present the aggregate regression statistics.[15]

3.3.1 House Prices and Employment Growth

I begin with baseline regressions of establishment (within-industry/county) employment growth on house price growth. Results show a strongly significant relationship between house prices and employment growth for establishments of young, old, and old/small firms. The result is also consistent with the notion that large businesses are less sensitive to local conditions, as the magnitude of the coefficient on house prices for employment growth at large businesses is much smaller. I instrument house prices with the Saiz housing price elasticity interacted with the change in state unemployment rates, including the change in the state unemployment rate as an additional control. These results, at the bottom of Table 1, show an increased point estimate on the house price coefficient that is still significant for both young and old. However, the point estimate for old businesses is driven by small firms. Overall, the results are economically meaningful for old/small and young firms, with a 1 percent increase in house prices leading to a roughly 0.19-0.26 percentage point increase in young employment growth and a 0.11-0.17 percentage point increase in old/small employment

[15] These results can also be represented as a single regression with full interactions of and age/size class variable. In the paper, I focus on significance by age/size, but undisclosed tests on joint significance and significant differences between coefficients across age/size categories are available upon request.

growth. In the pooled sample, the elasticity is between 0.15 and 0.25. By comparison, this is somewhat higher than what was found for only retail employment in Guren et al. (2021), who estimate elasticities between 0.05 and 0.16. These point estimates suggest that the national decline of roughly 18 percent can account for 2.7-4.5 percentage points of the decline in young employment (of about a 25 percent decline) and about 2.0-3.0 percentage points of the overall decline in small business employment.[16]

Table 1: Establishment-Level Employment Growth Regressions on House Prices by Firm age/size

	Total	Young	Old	Old/Small	Old/Large
OLS					
$\triangle$ HPI	0.1509	0.1903	0.1164	0.1143	0.0485
	(0.0251)	(0.0333)	(0.0212)	(0.0250)	(0.0128)
N	27,230,000	7,810,000	19,420,000	16,510,000	2,910,000
IV					
$\triangle\widehat{HPI}$	0.2453	0.2646	0.1872	0.1672	0.0570
	(0.0437)	(0.0603)	(0.0434)	(0.0507)	(0.0403)
N	19,000,000	5,670,000	13,330,000	11,430,000	1,900,000

Employment Growth Regressions on House Prices Note: Young < 5yo, Old>=5 yo, Small <500 employees, Large >=500 employees; includes log(DHS denominator), county effects, industry effects, time effects, and changes in county and state unemployment rates. $\triangle\widehat{HPI}$ indicates house prices instrumented by changes in state unemployment interacted with Saiz elasticities. See appendix for R^2 and first-stage tests.

3.3.2 Mortgage Share Approach

I now introduce an additional term that serves to highlight the influence of banking conditions on the impact of house prices on firm growth: pre-crisis shares of bank balance sheets within a state held as mortgages. Intuitively, a bank with a high mortgage ratio would be more sensitive to house price changes. In the regressions that follow, I normalize the mortgage share to have mean zero, so main effects can be interpreted as the effect of house prices in the state with the mean mortgage share. Table 2 presents the results from the regression. As before, house prices appear to have a large effect

[16] Interestingly, while there is a larger elasticity for young firms, it explains less of the overall decline.

Table 2: Emp. Growth Regressions by Firm Age/Size: Mtg. Share

	Young	Old	Old/Small	Old/Large
OLS				
$\triangle$ HPI	0.2800	0.1649	0.1676	0.0420
	(0.0341)	(0.0155)	(0.0182)	(0.0178)
$\triangle$ HPI*	0.1116	0.0633	0.0689	-0.0090
MTG_RATIO	(0.0325)	(0.0169)	(0.0210)	(0.0175)
N	7,810,000	19,420,000	16,510,000	2,910,000
Total IV				
$\triangle\widehat{HPI}$	0.3034	0.3199	0.2999	0.0808
	(0.1037)	(0.0799)	(0.0919)	(0.0830)
$\triangle\widehat{HPI}$*	0.0588	0.1605	0.1579	0.0326
MTG_RATIO	(0.0933)	(0.0627)	(0.0762)	(0.0738)
N	5,670,000	13,330,000	11,430,000	1,900,000

Employment Growth Regressions on House Prices and Mortgage Share Interactions Note: Young < 5yo, Old>=5 yo, Small <500 employees, Large >=500 employees; includes log(DHS denominator), county effects, industry effects, time effects, and changes in county and state unemployment rates. IV regression instruments for both house prices and interaction with mortgage share. See appendix for R^2 and first-stage tests.

on young businesses in both the OLS and IV specification. Point estimates are still consistent with table 1, implying an elasticity of 0.28 for young firms and 0.17 for establishments at old/small firms. Although the interaction with mortgage shares is significant for young firms in the OLS specification, I cannot reject the null under the IV specification. On the other hand, there is a significant response of employment among establishments of old businesses, in particular old/small firms, in response to house prices and their interaction with mortgage shares in both specifications. This supports the notion that a higher mortgage share among state banks impacts older firms through those banks, who could be more sensitive to house price shocks. As their balance sheets deteriorate, they pull back on their supply of credit to businesses, leading to reductions in employment for firms that are reliant on them. In this case, the firms most clearly affected are old/small firms. As before, old/large businesses are affected by house price shocks to a lesser extent than young and old/small firms.

To put the effect on old/small firms in context, a one standard deviation increase in mortgage share would lead to a roughly 30-50 percent increase in the elasticity for old/small firms. That is, the elasticity for a state with a mortgage share one standard deviation above the mean would be 0.46 relative to 0.3 at the mean. Thus a 18% decline in house prices would result in an additional 2.88 percentage point decline in growth rates for establishments in a state one standard deviation above the mean. Chodorow-Reich (2014), by comparison, finds that a one-standard deviation increase in exposure to credit supply shocks leads to a 1- 3 percentage point decline in the growth rate.

3.3.3 Bank Exit Approach

One would expect that increasing house prices would generally be associated with increasing employment, and an increased bank exit share should negatively impact employment. The first two rows of Table 3 confirm this result, with employment strongly correlated with housing prices, and bank exit negatively correlated with employment growth. The impact of house prices and bank exit vary across size/age categories. Establishments of young firms appear more sensitive to the direct effect of house prices. The bank exit effect seems to impact establishments of old/small firms, but the coefficient for establishments of young firms is not significant. For larger firms, only the direct effect of house prices is significant in the OLS specification. I then instrument for house prices, as before, using the county-level housing price elasticities to instrument for house prices in the second section of table 3. Results are broadly consistent with the OLS estimates, although the main effect of house prices on old/large businesses is no longer significant. Since bank exit is endogenous to firm performance, I also instrument bank exit with the interaction of house prices with pre-crisis bank balance sheet variables. These results are displayed in the bottom of table 3. In these specifications, it is still the case that bank exit has a sizable and significant effect on old/small firms, but a smaller and generally insignificant effect on young firms.

Overall, the point estimates on bank exit, or predicted bank exit, for old/small firms suggest that a one percent increase in bank exit yields a 0.03 to 0.23 percent

Table 3: Emp. Growth Regressions by Firm Age/Size: Bank Exit

	Young	Old	Old/Small	Old/Large
OLS				
△ HPI	0.1905	0.1152	0.1128	0.0480
	(0.0334)	(0.0211)	(0.0249)	(0.0132)
Bank Exit	0.0043	-0.0333	-0.0390	-0.0201
	(0.0271)	(0.0121)	(0.0127)	(0.0189)
N	7,810,000	19,420,000	16,510,000	2,910,000
Instrumented HPI				
$\triangle\widehat{HPI}$	0.2646	0.1875	0.1676	0.0570
	(0.0603)	(0.0432)	(0.0505)	(0.0402)
Bank Exit	-0.0154	-0.0317	-0.0387	-0.0205
	(0.0297)	(0.0129)	(0.0140)	(0.0233)
N	5,670,000	13,330,000	11,430,000	1,900,000
Instrumented Bank Exit				
△ HPI	0.1847	0.1088	0.1055	0.0472
	(0.0348)	(0.0216)	(0.0257)	(0.0125)
$\widehat{BE}$	-0.1288	-0.2140	-0.2305	-0.0530
	(0.1217)	(0.0633)	(0.0727)	(0.0814)
N	7,810,000	19,420,000	16,510,000	2,910,000
Instrumented HPI and Bank Exit				
$\triangle\widehat{HPI}$	0.2341	0.1800	0.1698	0.0277
	(0.0449)	(0.0342)	(0.0402)	(0.0387)
$\widehat{BE}$	0.0599	-0.1907	-0.1976	-0.2630
	(0.1592)	(0.0791)	(0.0923)	(0.0942)
N	5,670,000	13,330,000	11,430,000	1,900,000

Employment Growth Regressions on House Prices and State Bank Exit Share. Note: Young < 5yo, Old>=5 yo, Small <500 employees, Large >=500 employees; includes log(DHS denominator), county effects, industry effects, time effects, and changes in county and state unemployment rates. $\triangle\widehat{HPI}$ indicates house prices instrumented by changes in state unemployment interacted with Saiz elasticities. See appendix for R^2 and first-stage tests.

decline in employment at young firms. In the sample, the average asset-weighted bank exit rate was 2.2 percent across states-year observations, but there is substantial heterogeneity. For example, the interdecile range is about 5.9 percentage points, so establishments in a state-year with the 90th percentile bank exit rate would exhibit between 0.18 and a more substantial 1.33 percent decline in employment relative to identical establishments in the 10th percentile state-year observation.

3.4 Extensions

I further explore a number of extensions in the appendix. Deterioration in bank health due to house price decline could cause a decline in lending but not necessarily exit. In that sense, bank exit acts as an index that summarizes bank balance sheets. Alternatively, in the appendix, I consider an approach where all bank balance sheet variable are included directly, though it precludes instrumenting for house prices. I find results that are broadly consistent with the findings above. Another concern for macroeconomists is the effect of the housing crisis on productivity. Related literature discusses "cleansing" and "sullying" effects of recessions (e.g. Barlevy, 2002). Such effects could matter for aggregate productivity dynamics as entry, exit, and reallocation are important margins for determining productivity growth. To explore how the effects of house price growth vary by firm productivity, I use revenue data from the LBD to create a firm-level labor productivity measure. Broadly speaking, the results are mixed, with some suggestions that cleansing vs. sullying effects differ by firm type. I discuss the results at length in the appendix.

4 Model Outline

I now turn to a general equilibrium model to quantify the impact of a collapse in house prices on firm performance across the age distribution and on aggregate outcomes. To allow for comparison with the empirics, I specify a model in which house prices can influence firm outcomes through two channels–a bank credit supply channel and a collateral channel. I then consider alternative regimes in which I shut off each of the channels to evaluate their importance in influencing aggregates and their relative importance across the distribution of firms.

Time is continuous. There are three sectors: a representative household, an entrepreneurial production sector, and a banking sector. The household consumes nondurable goods and housing services both from owner-occupied houses and rental housing. It saves in the form of deposits, which are held by the bank. House prices will fall due to a shift in household preferences.

The key assumptions lie in the entrepreneurial sector and financial sector. Entrepreneurs produce using labor, which they hire from the household, and capital, which they need to accumulate over time. The accumulation of capital and hiring of labor are both impeded by financial frictions. In particular a collateral requirement potentially prohibits them from borrowing as much as they desire. The constraint depends on their assets, since they borrow against their own capital and, crucially, household equity in housing. Additionally, the model features life cycle dynamics that make analysis of entry possible.

The banking sector also plays an important role in propagating shifts in the change in housing preferences. Banks take deposits which they invest in three assets: mortgages, business loans, and rental housing. The key assumptions in this sector of the model is the exposure to house prices through its ownership of rental housing as an asset on its portfolio. Shocks to house prices translate to lower net worth for a bank holding rental housing. An internal incentive compatibility constraint limits the extent to which they can leverage their net worth, so lower net worth leads to tightening in the constraint, which in turn leads to tighter lending conditions for the household and businesses.[17]

4.1 Household Problem

The household maximizes utility over consumption C, leisure l, owner-occupied housing H, and rental housing H_R. It provides labor $L = 1 - l$ to producers at wage w. The household also saves by depositing D at deposit rate r in the banking sector. I require that each household must borrow through mortgages M to finance housing

[17] Crucially, I will be able to track the effects of shocks by age, including the effects on entry. The model has no geographic variation, which required additional exploration of the size dimension in the empirical analysis. Since the focus is on mechanisms driving differences in responsiveness of young and old firms, the focus of my analysis is on the age dimension. I now turn to a more detailed description of the model.

expenditures. Formally, the household problem is given by the following:

$$\max_{\{C,L,H_{new},m\}_{t=0}^{\infty}} \int_{t=0}^{\infty} e^{-\rho t} U(C, 1-L, H, H_R) \tag{6}$$

$$\dot{D} = wL + rD + \Pi - R_h H_R - d_m - \frac{\phi_d}{2}\frac{d_m^2}{M} - C \tag{7}$$

$$\dot{H} = H_{new} - \delta_h H \quad ; \quad \dot{M} = q_h \left(\dot{H} + \delta_H H\right) + r_m M - d_m \qquad (M \geq 0) \tag{8}$$

Note here that d_m are mortgage payments. First order and envelope conditions imply (suppressing utility function arguments):

$$w = \frac{U_L}{U_C}; \quad R_h = \frac{U_{H_R}}{U_C}; \quad (\rho - r) U_C = \frac{d}{dt} U_C \tag{9}$$

$$q_h (\rho + \delta_h) \left(1 + \phi_d \frac{d_m}{M}\right) U_C = U_H + \frac{d}{dt} q_h \left(1 + \phi_d \frac{d_m}{M}\right) U_C \tag{10}$$

$$\left(\rho \left(1 + \phi_d \frac{d_m}{M}\right) - r_m\right) U_C = \frac{d}{dt} \left(1 + \phi_d \frac{d_m}{M}\right) U_C \tag{11}$$

Equation (7) gives standard static expressions of prices as marginal rates of substitution and the standard intertemporal Euler equation. Equation (8) governs the choice between present consumption and durable owner-occupied housing. Equation (9) gives the intertemporal Euler using mortgage rates, which can deviate from the deposit rate due to the adjustment cost. Imposing steady state (where time derivatives are equal to zero), gives the usual condition $r = \rho$, and the steady state relationship between spreads and adjustment costs $r_m = r + \rho \phi_d d_m$. In steady state we have:

$$q_h = \frac{U_H}{(\rho + \delta_H)(1 + \phi_d d_m) U_C} \tag{12}$$

Equation (10) expresses house prices as the marginal rate of substitution between housing and consumption. Finally, we have the steady state rent to price ratio: $\frac{R_h}{q_h} = (\rho + \delta_h) \frac{U_{H_R}}{U_H}$.

4.2 Production

The entrepreneurial sector combines a modified Hopenhayn (1992) model of firm entry and exit, similar to Akhtekhane (2017), with a model of firms whose borrowing and operations are inhibited by credit market frictions. The model extends work by Kaplan et al. (2018) to a producer's problem where borrowing constraints are endogenous to producer assets and housing collateral. Firms are able to borrow, but only up to a certain fraction of their owned capital plus some collateral from the aggregate housing stock.

Entrepreneurs are intermediate goods producers, where goods are differentiated according to a monopolistic framework with the following aggregator:

$$Y = \int_i y_i^\gamma di \tag{13}$$

Where y_i is the individual i's physical output. A final goods producer operates this aggregator technology and sells the final output Y, which is the numeraire. Payments to producers are made in the numeraire good as well. This yields the pricing function (which is decreasing in own output since $\gamma < 1$): $p_i = y_i^{\gamma-1}$. Ultimately, profits sent to the household will be $\Pi = Y - \int_i p_i y_i d_i = (1-\gamma) Y$.

4.3 Continuing Firms

Continuing intermediate firms have liquid assets/borrowing b, and illiquid productive physical capital k. They hire labor each period at wage rate w, which combines with capital and plant specific productivity z to produce physical output. Thus the state of the production sector can be described at any time t by the joint distribution $\mu_t(dz, dk, db)$. Liquid assets pay lower interest rate r when the entrepreneur saving, and higher borrowing rate r_ℓ. This borrowing rate also affects the cost of labor, indicating a need to use financial intermediaries to pay workers. Upon producing, earning interest/paying interest on liquid assets, and paying workers, the entrepreneur can choose to invest profits or consume. Investment is subject to convex adjustment costs $f(i,k)$, and capital depreciates at rate δ. Log productivity follows a Ornstein-Uhlenbeck process with parameters μ_z and σ_ϵ. Their problem is defined as follows:

$$V(z,k,b) = \max_{c,h,i} \int_0^\infty e^{-(\rho+\zeta)t} u(c_t)dt \tag{14}$$

$$s.t. \quad \dot{b} = z^\gamma k^{\gamma\alpha} h^{\gamma(1-\alpha)} + r(b)b - w\left(1+r_\ell\right)h - i - f(i,k) - c$$

$$\dot{k} = i - \delta k$$

$$dlog\left(z\right) = -\mu_z log\left(z\right)dt + \sigma(z_t)dW_t$$

$$-b + w(1+r_\ell)h \leq \xi k + \xi_h q_h H$$

$$r\left(b\right) = \begin{cases} r, & b > 0 \\ r_\ell, & b < 0 \end{cases}$$

We can anticipate how changes in house prices will affect firms. House prices directly affect firms by tightening collateral constraints $\xi_h q_h$, and as we will see, house prices affect borrowing rates via the banking sector.[18]

4.3.1 Entry and Exit

Existing firms exit the economy in two ways: a random exogenous exit that arrives at rate ζ or hitting the borrowing limit without the ability to generate non-negative savings (and therefore abide by the constraint). There are states that are feasible for firms in the upper part of the productivity distribution, but firms would be "underwater"–unable to generate positive cash flow even if consumption is 0–if they had sufficiently low productivity. These firms must either get lucky with a positive productivity shock that allows them to improve their balance sheet, or they hit the boundary and are forced to liquidate via bankruptcy. In this case, the ex-entrepreneur is assumed to receive constant payoff of $c_{exit}(z,k,b)$ in the limbo state unless hit by the death shock,

[18] The influence of finance costs and the collateral constraint on the labor margin creates labor wedges to which, as discussed in Chari et al. (2007), aggregate outcomes are sensitive.

and so the value function for such firms is by definition $v(z,k,b) = \frac{c_{exit}(z,k,b)}{\rho}$.

There is a continuum of potential entrants on the interval $[0,1]$, and the realized flow of entrants m is governed by a modified free-entry condition:

$$m = \overline{m} exp\left(\eta\left(\int_0^1 v\left(z, k_{ent}, b_{ent}\right)\psi(z)dz - c_e\right)\right) \tag{15}$$

Where η governs the elasticity of supply of entry with respect to deviations of the free entry condition from zero, and $\overline{m}$ is a parameter that relates the mass of the entry distribution to the mass of continuing firms. Compared to the Hopenhayn (1992) model, the supply of entrants is governed by η and is not infinitely elastic. Entrants are endowed with a pre-defined minimal amount of capital and no outstanding debt.[19]

4.4 Banking Sector

This model is a continuous time extension of Gertler and Kiyotaki (2015). Banks are subject to an internal enforcement constraint which generates a spread between the lending rate and the deposit rate. In previous literature, intermediaries are often exposed to risk by holding equity claims, rather than debt claims with default risk. There, equity claims on capital had associated capital prices, which could fluctuate and therefore impact bank net worth. However in my model, banks are exposed to equity claims on housing. Banks take deposits from households and fund mortgages, rental housing purchases, and business loans with them. However, their ability to lend is subject to an incentive constraint that requires some equity or "skin in the game" from the bank. That is, the bank is limited in its ability to leverage its initial wealth. I model this as a leverage constraint, where lending capacity depends on the bank's net worth. This constraint generates a positive spread between the lending rate and the deposit rate.

In the real world, bank assets like mortgages and MBS can depreciate in response

[19] Following techniques discussed in Kaplan et al. (2018), as well as related papers, I set up the Bellman equation as shown in appendix A and solve the model numerically.

to house price shocks, leading to lower bank net worth and reducing lending capacity. In this model, the exposure to rental housing prices represents exposure to house price fluctuations through mortgages and other lending related to owner-occupied homes as well as commercial properties.[20]

4.4.1 Bank Problem

Banks make choices over a portfolio of assets. They lend to businesses via business loans ℓ, they lend to housing markets via mortgages m, and they own rental housing H_R which yields rental return R_h and is valued at price q_h.[21] All assets are subject to a flow cost ψ that is proportional to the asset's value. Bank net worth is the value of assets less deposits, $n = q_h H_R + \ell + m$, and banks have linear preferences in end of life net worth, discounting it by σ due to exogenous death. The bank's objective is thus given by:

$$V(l, m, H_R) = \max_{\dot{l}, \dot{m}, \dot{H}_R} \int_0^\infty \left(1 - e^{-\sigma}\right) e^{-(\rho+\sigma)t} n \, dt \tag{16}$$

$$s.t. \int_0^\infty \left(1 - e^{-\sigma}\right) e^{-(\rho+\sigma)t} n \, dt \geq \theta a$$

$$\dot{n} = \left(\frac{\dot{q}_h + R_h - \delta_h}{q_h} - \psi\right) q_h H_R + (r_\ell - \psi)\,\ell + (r_m - \psi)\, m - rd$$

$$n = a - d \qquad\qquad a = q_h H_R + \ell + m$$

In the appendix, I walk through details of solving this problem. The evolution of the bank leverage ratio is given by a first order differential equation:

$$\dot{\varphi}_t = (\rho + \sigma - r - (R_a - \psi - r)\,\varphi_t)\,\varphi_t - \frac{(1 - e^{-\sigma})}{\theta} \tag{17}$$

[20]This is similar to work by Gertler and Karadi (2011) and Gertler and Karadi (2015), who model exposure to capital price fluctuations via equity claims on capital. In reality, this stands in for exposure to debt that is potentially subject to default.

[21]While businesses do face a cost equivalent to the lending rate associated with bank facilitation of wage payments, these payments are not an asset for the bank.

Equation (21) shows that changes in bank leverage does not depend on bank size, but depends negatively on the spread. However, I show in the appendix that for a stationary distribution where $\dot{\varphi}_t = 0$, leverage is given by the solution to a quadratic equation where, under relevant parameterizations, leverage ratios in steady state are positively associated with credit spreads.

4.4.2 Bank Aggregation

Since bank net worth always grows, bank exit and entry to ensure stationary aggregates. Total net worth and assets in the banking sector are defined as:[22]

$$N = \int_0^1 n_j d_j \qquad A = \int_0^1 a_j d_j$$

Defining $\Phi = \frac{A}{N}$ as the leverage ration in the banking sector as a whole, with W_b parameterizing the amount of wealth endowed to entering banks and $w_b = \frac{W_b}{N}$ as the share of entering bank net worth to total net worth, we have the following growth rate for total bank net worth:

$$\frac{\dot{N}}{N} = e^{-\sigma} \left[(R_a - \psi - r) \Phi + r \right] + \left(1 - e^{-\sigma} \right) (w_b - 1) \tag{18}$$

Combining with the individual bank solution problem, this law of motion is key for defining an equilibrium and determining interest rate spreads.

4.5 Equilibrium

An equilibrium for this economy is a path of the production sector distribution $\mu_t(dz, dk, db)$, household aggregates $\{D(t), H(t), H_R(t), L(t), C(t), d_m(t), M(t)\}$, corresponding bank aggregates, and prices $\{w(t), r(t), r_m(t), r_\ell(t), q_h(t)\}$ such that the decisions described by optimal conditions and constraints for the household, producers, and banks hold, and markets clear for all t. I describe these market clearing

[22]Likewise, denote $H_R = \int_0^1 h_{R,i} d_i$, $M = \int_0^1 m_i di$ and $\boldsymbol{\ell} = \int_0^1 \ell_i di$.

conditions explicitly in the appendix.[23]

4.6 Transition

To represent a crisis, I explore a temporary exogenous shock to housing preference parameters. The shock is completely unanticipated by agents, who have not expectation it will occur. Upon realization of the shock, agents have perfect foresight over the future path the economy will take. The shock itself, displayed graphically in the appendix, is a sharp decline in both the preference for housing in general (governed by parameter ν_h) and owner-occupied housing in particular (given by parameter ϵ_h), and a gradual recovery in both parameters to their initial values. Such a shock broadly captures the decline and slow recovery of house prices and home ownership rates.

I primarily consider an open-economy version of the model where the deposit rate is fixed. This implies that all adjustment to interest rates via the spread directly affect firms through borrowing costs. This assumption is more realistic in the short-run, when sticky prices and the zero-lower bound inhibit the flexible deposit rates, but perhaps less justified at a longer horizon. So, I also consider a model with a flexible deposit rate in the appendix.[24]

5 Preferences and Calibration

I consider the set of moments described in appendix B for calibration. Some parameters are jointly determined to match targets from data, and some are based on standard values in the literature or aggregate estimates of the parameter. All rates are annual, with long-run averages used for smoothing.

For the household, I use a utility function that is additively separable in consumption/labor and housing. The consumption/labor preferences are GHH (specifically log) with a linear disutility of labor, and housing preferences are CES with housing

[23]Implicitly, as housing depreciates it must be replaced. I assume this construction occurs in a competitive sector that produces housing with a fixed cost κ_H and consumes: $q_h\delta_h - \kappa_H$.

[24]Given this path of parameters, I employ a "shooting" algorithm where a guess is made for the path of a key aggregate variable, the lending rate in this case. The addition of an endogenous price requires an extra guess for the shooting algorithm.

taste ν_h and owner-occupied housing taste ϵ_h:

$$U(C, 1-L, H, H_R) = ln\left(C - \nu_l L\right) + \nu_h \left(\epsilon_h H^{1-\sigma_h} + \left(1-\epsilon_h\right) H_R^{1-\sigma_h}\right)^{\frac{1}{1-\sigma_h}} \tag{19}$$

These preferences imply that the wage will be pinned down by the disutility of labor parameter $w = \nu_l$, and does not change even in transition. Thus, the model will have some similarities to a sticky-wage framework. This assumption is less justifiable in the long-run, but in line with sticky price models over the short run.[25] Crucially, in the Hopenhayn model, the wage is key for determining entry rates in steady state, and so this parameter is chosen to match the entry rate in the US in 2005 (about 10 percent). The parameters related to housing and mortgage costs are target the owner-occupied share, house price-to-rent ratio, and mortgage debt to housing value ratio. The discount rate ρ is standard and δ_h is consistent with BEA data on housing depreciation.

The chosen persistence of firm productivity μ_z is central to the range of potential estimates in Asker et al. (2014).[26] Likewise with depreciation δ, capital share α, markups γ, housing depreciation δ_h, and the discount rate ρ, I use standard values from the literature. I set the entry cost c_e to be fractionally lower than the value of entry. An alternative would be to tie the opportunity cost of the entrepreneur to a counterfactual labor market outcome.

The production parameters that are calibrated to moments in the literature include the standard deviation of shocks, which I calibrate to target dispersion in TFPR from Cunningham et al. (2021), and the quadratic adjustment cost parameter to target the standard deviation of investment rates from Cooper and Haltiwanger (2006). I calibrate the collateral constraint to target data on corporate debt to GDP, entry

[25]This also implies that employment is fully driven by firm demand, so the parameter $\overline{m}$ is key to determining employment.

[26]The evidence from Midrigan and Xu (2014) and Moll (2014) suggests that self-financing can at least partially undo the effect of financial frictions in the long-run, at least under higher levels of persistence. However, Moll (2014) finds that transitions can still be slow even under persistent processes.

Calibration					
Parameter	**Value**	**Target Description**	**Data**	**Model**	**Source**
Household					
Targeted					
ν_l	0.686	Entry Rate	0.1	0.1	BDS (2005-2006 average)
ϕ_d	2.89	Mtg. debt-to-housing	0.39	0.42	FF (2004-2006 average)
ν_h	10.7	Owner-occupied share	0.685	0.685	Census (2002-2007 average)
ϵ_h	0.892	q_h/R_h	12	12	Garner and Verbrugge (2009)
Selected					
ρ	0.04	Deposit Rate	4%	4%	–
δ_h	0.03	Housing Depreciation	–	–	BEA
Production					
Targeted					
α	0.370	Labor Share	0.61	0.6	BEA (2004-2006 average)
γ	0.9091	Markups	0.1	0.1	Basu and Fernald (1997)
σ_ϵ	0.035	IQR of TFPR	0.5	0.51	Cunningham et al. (2021)
ϕ	0.85	S.D. of (I/K)	0.337	0.358	Cooper and Haltiwanger (2006)
ξ	1.25	Corporate Debt-to-GDP	0.398	0.376	FF/ BEA (2004-2006 average)
κ_e	2.5	Emp. Entry Rate	0.024	0.022	BDS
$\overline{m}$	0.0082	EPOP	0.628	0.628	BLS (2004-2006 average)
c_b	0.1	$\frac{q_h H}{Y}$	1.05	1.08	BEA/FF
Selected					
μ_z	0.151	Prod. Persistence	0.151	0.151	Asker et al. (2014)
δ	0.069	Capital Depreciation	0.069	0.069	Cooper and Haltiwanger (2006)
ζ	0.067	Nondistressed Exit	0.67	0.67	Headd (2003)
η	1	Elasticity of Entry	–	–	See appendix
c_e	-5.5	Entry Cost	–	–	–
Banking					
Targeted					
θ	0.165	Leverage	10	10	FDIC (2005)
ψ	0.0147	Credit Spread	1%-4%	1.8%	ICE BofA
Selected					
σ	0.08	Death Rate	8%	8%	BDS (2005-2006 average)
ω_b	0.1	Entrant size/Mean Size	–	–	–

Note: Data sourced from Bureau of Economic Analysis (BEA), Federal Reserve Flow of Funds (FF), US Census Bureau (Census), and the Bureau of Labor Statistics (BLS) are denoted as such. Data from the BEA, FF, and BLS were accessed through FRED. FDIC targets are based on my tabulations from state bank data. ICE BofA data from FRED displays range from "Investment Grade" options-adjusted spreads to "high-yield." FF mortgages reflect all single-family mortgages, and housing from the flow of funds includes all household owner-occupied real estate.

mass $\overline{m}$ to pin down labor as a fraction of the population, and entry level capital to match employment-weighted entry rates from the Census Bureau's Business Dynamics Statistics.

The final piece of the puzzle for the producing sector is the elasticity of entry is a free parameter that matters greatly for the response of entry to a recession. I investigate the effects of this parameter in the online appendix, but focus on a parameterization that yields a reasonable response of entry to the housing crisis. The value of 1 is clearly very low compared to the infinite elasticity in a Hopenhayn model, perhaps suggesting a model along the lines of Jovanovic (1982) or Decker (2015) would be of interest for future research.

Finally, I use financial sector parameters to support a leverage ratio of 10, which is in the range discussed in Gertler and Kiyotaki (2015), and an intermediation cost 180 basis points (Phillipon, 2015). I select the fraction of bank net worth re-distributed to new banks which implies the size of a new bank is 10 percent of the average bank. Consistent with BDS data, I set the exogenous bank death rate to 8 percent. I can then calculate the internal compatibility constraint parameter θ consistent with a target leverage ratio.

6 Results

I now turn to analysis that explores the response of the calibrated economy described above to a housing collapse. Specifically, I focus on a change in demand for overall housing in ν_h and owner-occupied housing ϵ_h. This allows for both a decline in house prices q_h and a fall in the price-to-rent ratio along with a decline in owner-occupied housing. The model is solved where dt is equivalent to a year. The shock declines rapidly for two years before recovering very slowly over three decades, as displayed in the apendix. It is worth noting what this crisis does *not* represent. There is no shock to collateral constraints ξ or financial intermediary constraint θ. Furthermore, there is no shock to aggregate TFP, as in Gertler and Kiyotaki (2015). Although something along the lines of a shock to intermediation parameters, or TFP, is likely in the context of the Great Recession, this paper shows the potential for endogenous financial tightening to contribute to the decline in aggregate outcomes.

6.1 Aggregate Results

I focus on a small open-economy version of the model where the deposit rate is fixed.[27] Results for key aggregates are shown in figure 3. The change in housing preferences results in a change in house prices of 17.5%, roughly in line with the decline in house prices observed in the FHFA data during the Great Recession. Crucially, owner-occupied housing falls as well, although more sharply than observed during the housing crisis.[28] The timing of the housing price collapse is somewhat inconsistent with the experience in the U.S. House prices fall sharply in the model and begin to recover slowly after two years. House prices declined more slowly over the course of six years from 2006 to 2012 in reality, suggesting either a series unexpected shocks, or perhaps a slow learning of the severity of the shock which elongates the decline.[29] On the financial side, bank leverage rises sharply and we see a resulting increase in credit spreads of about 70 basis points on impact, which is low compared to credit spreads in the data, which rose by between 300 and 500 basis points.

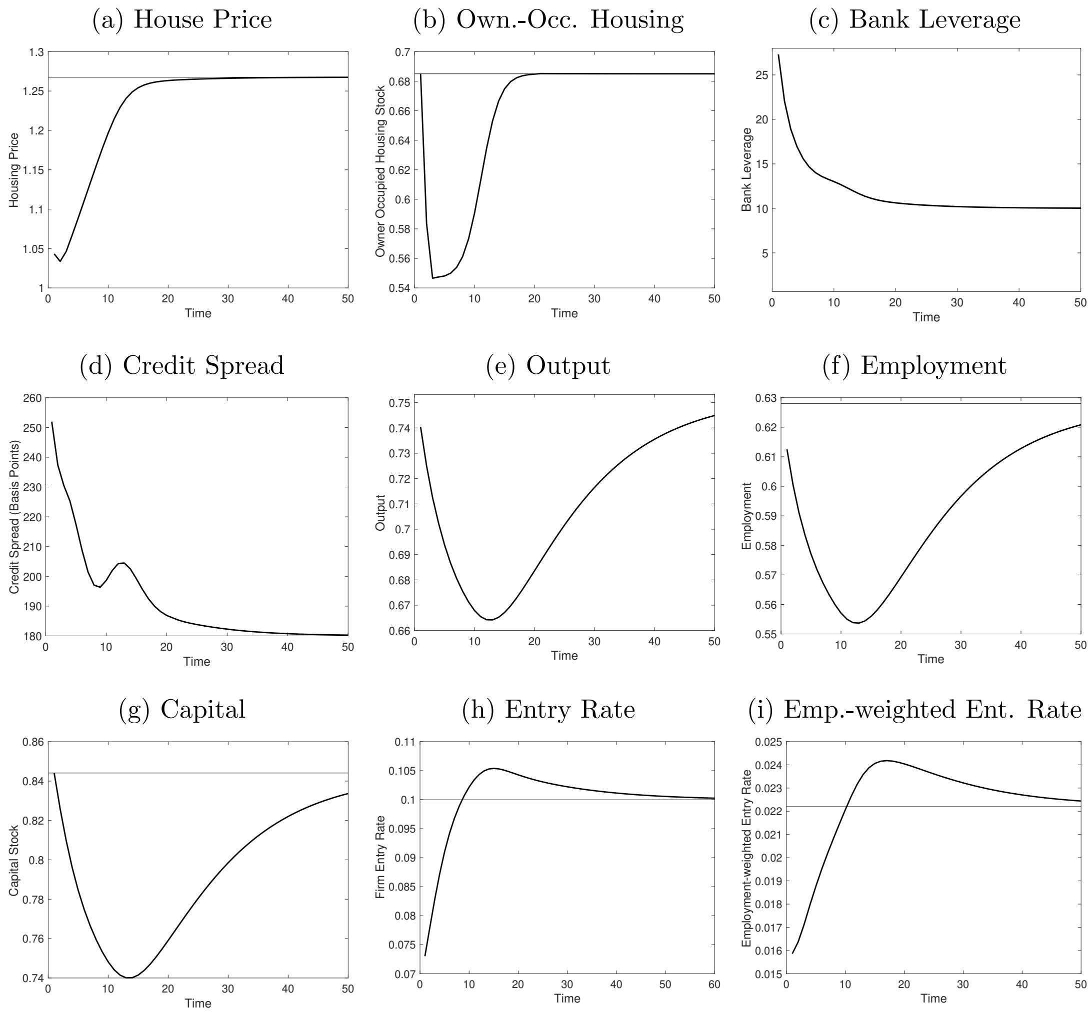
Overall, the shock to housing preferences leads to a housing crisis with falling housing collateral values and tightening credit conditions, consistent with the experience of the U.S. in the Great Recession. This crisis has real effects in terms of output and employment, as tightening credit conditions and lower house prices lead to severe contractions in output, employment, and the capital stock. On impact, employment falls more sharply than output, as the entry rate collapses by over 2.5 percentage points before eventually recovering by the end of the first decade after the crisis.

[27] I explore a closed-economy version of the model in the appendix.

[28] This tightens collateral constraints more when owner-occupied housing declines, but the decline in house prices is likely on the low side. For example, by January 2012 the Case-Shiller house price index had fallen by as much as 26 percent from its peak in 2005.

[29] Slowing down and extending the decline in the shock to six years does little to change the picture, as the revelation of the shock is what causes the dramatic decline.

Figure 3: Housing Crisis: Aggregate Impulse Responses



But the damage is largely done, as output and employment persistently deviate from long-run steady state. Output falls more than 10 percent below its steady state (equivalent to trend output in the data) with the employment to population ratio falling as low as 55 percent. This is more severe than the decline in the data, when EPOP fell to 58 percent, likely due to the model capturing the experience of small businesses, especially young businesses, more than large older businesses which dominate aggregate employment in the data.

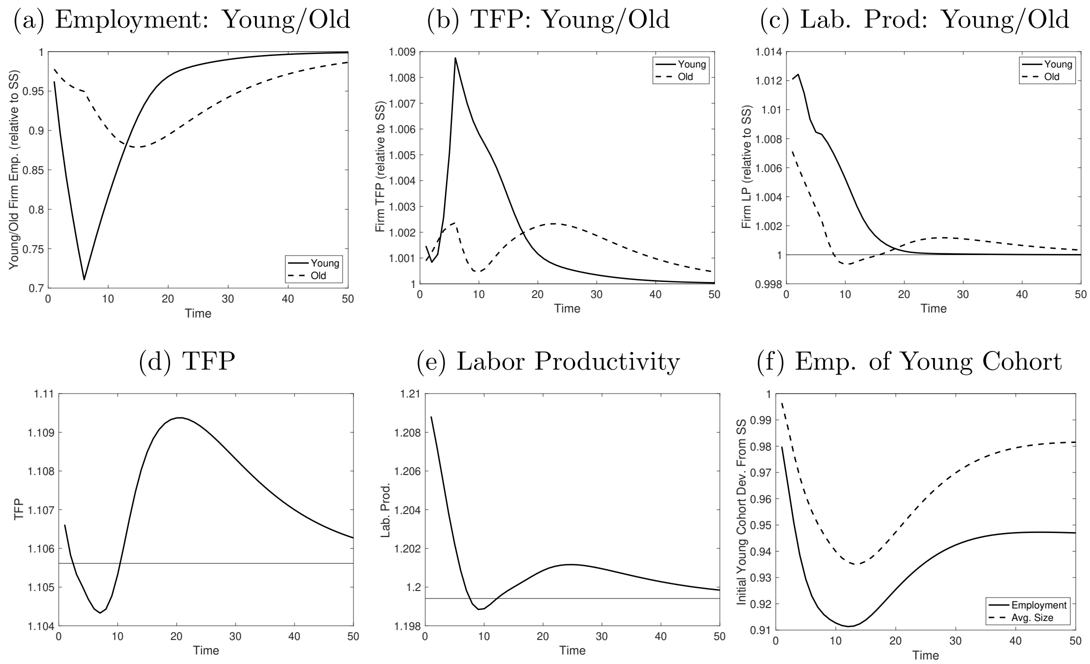
To see this, I display the decline in young (<5 years) vs. old firm employment from the model relative to the steady state in figure 4. Here, we see that young business employment drops about 3 percent on impact, implying a rough aggregate elasticity of about 0.17 that is in line with the OLS estimate and within a plausible range of the IV results from table 1. Employment at young firms further falls by 30 percent over five years due to the cumulative loss of young firms through lower entry, as seen in panel (h) of figure 4, roughly in line with the data displayed in figure 1. While entry is an important driver of aggregate results, existing young firms also suffer, which I demonstrate by simulating a "young" cohort at the time of the shock (so it does not incorporate entry) relative to a counterfactual cohort in the steady state where no shock occurs, displayed in panel (f) of figure 4. This shows a persistent and large impact on this cohort as continuing young firms cut employment and the exit rate increases, leading to lower long-run contributions of the cohort. Similar to the evidence provided in Sedlàček and Sterk (2017), this effect is due to both the extensive margin, in this case exit, and the intensive margin, average size of continuing firms. In the long run, exiting firms mean that overall employment never recovers, but neither does average size due to negative selection effects into exit created by aggregate conditions.[30]

On the other hand, employment falls by about 2 percent for older firms on impact, but eventually declines by about 12 percent after more than a decade. Some of this is due to the cohort effects, as some businesses (especially young ones) that experienced the crisis were not able to grow as quickly or were forced to exit, curtailing or removing their potential to contribute in the long run to old employment. In this way, while the crisis had direct short-run impacts on older businesses, the pattern of young employment leads the medium to long-run pattern in older business employment.

Productivity rises for young and old businesses, displayed in panels (b) and (c) of figure 4. This is perhaps surprising since recessions are associate with lower aggregate TFP, but unsurprising since tighter collateral constraints and higher interest rates

[30]The mechanism in the quantitative model in Sedlàček and Sterk (2017) differs in that selection into different product markets determines employment growth. In this case, selection into exit disproportionately affects more productive (but vulnerable) firms.

Figure 4: Housing Crisis: Age Profile and Productivity Responses



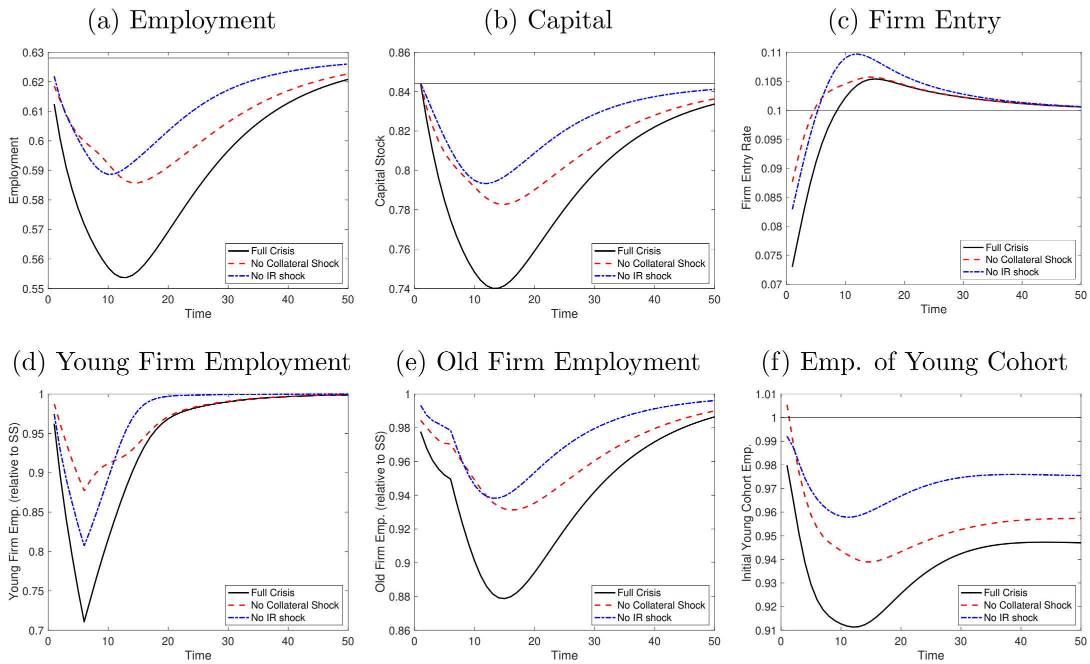
Note: Panels (a)-(c) are measured relative to steady state values . Panel (f) tracks a cohort who is young at the time of the initial shock relative to a steady state cohort.

are associated with higher labor productivity. Further, selection within firm types could lead to cleansing effects, as lower productivity firms exit. On the other hand, if relatively productive firms are forced to cut employment more (or exit), then a sullying effect would lead to lower aggregate productivity. Although there is a small initial rise in aggregate TFP at impact, this sullying effect quickly takes over in the medium term before giving way to higher productivity. Given the relative increase in TFP within cohorts, much of the sullying effect is due to the disproportionate impact on young businesses during the downturn, and the increase in productivity in the medium-run corresponds with a recovery in entry. Labor productivity shows a similar pattern. However, these effects are fairly small, with both labor and total factor productivity remaining within one percent of steady state levels.

6.2 Partial Equilibrium Counterfactuals

Young businesses are more susceptible to the housing crisis in the model, but which channels are important for young vs. old firms? To answer this question, I investigate the effect of the two key objects that affect producers in this housing crisis: collateral values and interest rates. In this first set of counterfactuals, I conduct partial equilibrium analysis where I shut down each channel in turn. First, I fix the value of housing at its steady state level in the firm's collateral constraint, but maintain the path of interest rates found in the full crisis. Second, I maintain a fixed spread while feeding in the change in housing collateral. The results are displayed in figure 5.

Figure 5: Counterfactual Experiments: Collateral vs. Credit Channels



Note: Measures are relative to steady state values in (h) and (i).

While both channels are important for the overall decline (in a partial equilibrium sense), there is a differential response of young vs. old businesses, and entrants in particular. Consistent with the empirical analysis, entry is particularly responsive to the collateral channel, falling by almost half a percentage point more. However, both counterfactuals present a much less pronounced drop in entry, suggesting that both are important for new business formation in the model. Further, the effect of the crisis on entry is cut relatively short, with entry attaining its steady state level in roughly half the time required in the full crisis. Further still, the entry rate overshoots more in both counterfactuals, in particular when the interest rate channel is shut down. Thus, the economy "snaps back" quickly with an influx of new entrants.

Consistent with the empirical work, the collateral channel appears to be a bigger driver of employment responses at young firms than the interest rate channel, at least initially. As shown in panel (d), employment falls by almost 20 percent at young firms in the counterfactual with only the collateral channel, accounting for roughly 2/3 of the decline. However, the credit channel appears to be very important for the persistence of the effect of the crisis on young firms. There is a much quicker recovery in entry without the effect of interest rates. Further, the initial set of firms who are young, displayed in panel (f), are severely affected in the long-run by the interest rate channel, although the the collateral channel is more important on impact.[31]

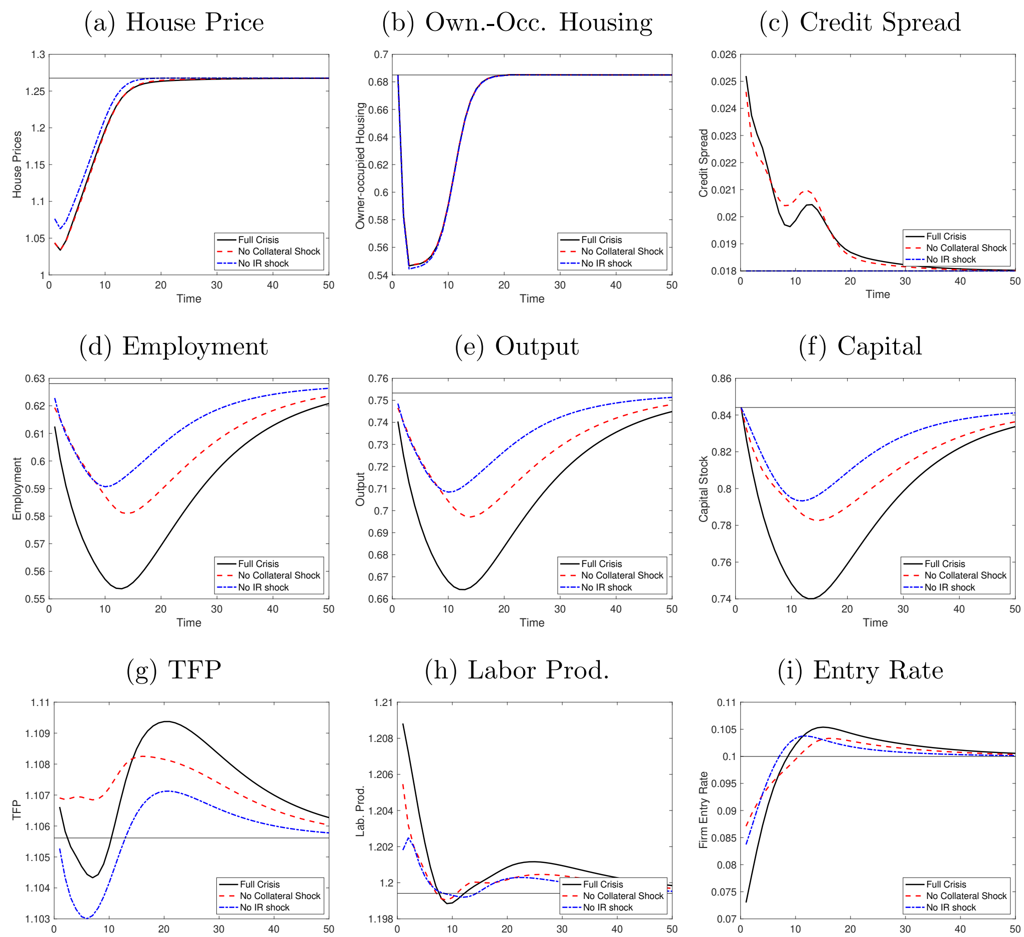
In the initial onset of the crisis, the importance of the two channels is reversed for older firms, as shown in panel (e) of figure 5. Employment is more than twice as responsive to the shock to interest rates on impact than collateral values. After a decade the decline in employment is similar in both counterfactuals, but the credit channel again has a more persistent effect than the collateral channel. Comparing old firms to young firms, there is a disproportionate response of young firms in both counterfactuals. Young employment falls to roughly 88 percent of its steady state level and old employment falls to only 94 percent in the "no collateral shock" counterfactual. However, there is an even more unbalanced response when collateral channels are active.

[31]It is likely best to connect my empirical work with the response of employment on impact, since the responses are annual changes.

6.3 General Equilibrium Counterfactuals

In the above section, I ignored the impact of shutting down various channels on price determination. This ignores potentially important interactions between channels and the endogenous response of households in these counterfactuals. While this analysis was useful for investigating the relevance of each channel for different firm types, counterfactuals that take into account general equilibrium effects help demonstrate the effect of each channel on aggregates.

Figure 6: Housing Crisis: General Equilibrium Experiments



In the case where the collateral channel is eliminated, I fix the collateral value at its steady state level, feed in the same preference shock as the full crisis, and compute the interest rate path and house price path that is consistent with the household and bank problem.[32] For the counterfactual with no interest rate channel, the lending rate is essentially a fixed spread over the deposit rate, which is taken as given in the small open economy. Given preferences, the interest rate and wage paths are constant in this second experiment. However, house prices potentially respond differently than in the full crisis, as they enter into optimal household decisions. Shutting down interest rate fluctuations, then, can either dampen or amplify the housing shock.

The results from these general equilibrium experiments are displayed in figure 6. The top row illustrates how shutting down either channel can change the impact of the other channel. For example, shutting down interest rates also leads to a smaller drop in house prices (although owner-occupied housing falls by slightly more), mitigating the collateral effect. This suggests that the credit supply channel affects the collateral constraint channel by amplifying house price shocks. Likewise, fixing collateral for firms leads to a somewhat milder increase in the credit spread on impact, although it does not fall as quickly during the initial recovery. Fixing housing collateral has a negligible impact on the performance of house prices and housing markets in general.

The upshot is that the interest rate channel is somewhat more important for aggregate performance, but both channels are necessary to create the large aggregate response seen in the full crisis. Employment and output fall by more on impact, reach a lower trough, and take longer to recover in the counterfactual with the credit channel than the counterfactual with the collateral channel only. However, TFP falls more in the collateral channel only scenario than in the full crisis, while TFP does not fall at all in the experiment with only a credit channel. This suggests that the collateral channel creates a sullying effect which drags down TFP, while the credit channel enhances cleansing through the selection channel. Further, the importance of the collateral channel is illustrated by its accounting for over 40 percent of the peak-to-trough decline by itself. Further, employment falls by almost 3 percentage points more in the full crisis than when only an interest rate channel is present.[33]

[32] House prices change for households and the bank, but not in firms' collateral constraints.

[33] Results across the age distribution (not displayed) are qualitatively consistent with the partial

6.4 Discussion

The model presents a picture that is consistent with the empirical work in this paper: when house price shocks occur, there is strong evidence in the data and the model that older (small) firms are responsive to the credit supply channel. While the credit channel matters for young firms in the model, and it is hard to rule out its relevance in the data, the bigger impact of house prices on young firms appears to come from other channels in both the model and the data.

For policymakers addressing financially-driven recessions, evidence from the model suggests the type of financial pressure can be important for targeting policy. Banking conditions do not appear to be driving the relative performance of young businesses. As suggested by results from the empirical literature, collateral values are important for businesses in the model. In this context, collapsing collateral constraints hit young businesses relatively hard. That credit access, not interest rates, is more powerful for explaining the collapse in both business formation and young business expansion. Thus, programs focusing on securing credit for new businesses are potentially more helpful.

7 Conclusion

This paper presents evidence on the impact of house prices working through local bank credit supply channels to affect firm growth in the Great Recession, and constructs a macroeconomic model that is consistent with the evidence. In both the data and the model, bank credit matters for old firms, but not as much for young firms. In both the model and the data, there is a disproportionate response of young businesses to house prices, driven primarily by mechanisms other than bank credit supply. In the model, as motivated by previous empirical work, a collateral channel is particularly important for young business' responses to house prices.

equilibrium analysis, suggesting the partial equilibrium experiments capture the influence of the channels across the age distribution.

In the model, the credit supply channel accounts for much of the aggregate response of the economy to a housing crisis, particularly the persistence of the recession. The impact on collateral values is also important in the aggregate because it reduces entry and activity at young firms disproportionately, contributing significantly to the severity of the recession as well. These findings are relevant for policy makers seeking to effectively combat economic downturns, as targeting only one channel may leave the job half done.

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A Model Details

A.1 Stationary Steady State

Using Ito's Lemma to write this as a Bellman equation, and specifying a quadratic cost function $f(i,k) = \phi\frac{(i-\delta k)^2}{2k}$, we have:

$$(\rho+\zeta)\, v(z,k,b) = \max_{c,i,h} u\,(c) + v_b(z,k,b)\left(z^{\gamma}k^{\gamma\alpha}h^{\gamma(1-\alpha)} + r(b)b - w(1+r_\ell)h - i - \phi\frac{(i-\delta k)^2}{2k} - c\right)$$

$$+ v_k(z,k,b)\,(i-\delta_k) + v_z\mu_z z + \frac{1}{2}\sigma_z v_{zz}(z,k,b)$$

Standard first order conditions imply:

$$h = \left(\frac{\gamma\,(1-\alpha)\,z^{\gamma}k^{\gamma\alpha}}{w\,(1+r_\ell)}\right)^{\frac{1}{1-\gamma(1-\alpha)}} \tag{20}$$

$$u'(c) = v_b \tag{21}$$

$$i = \frac{k}{\phi}\frac{v_k}{v_b} + \delta k \tag{22}$$

One additional feature of the algorithm is to define v_b at the boundary by using the last two equations above, the budget constraint when $\dot{b} = 0$, and the the guess for v_k (implied by the guess, or updated guess, for v).[34]

B Market Clearing Conditions

Market clearing conditions in equilibrium for all t:

$$Y(t) = \int \left(zk^{\alpha}h(t)^{1-\alpha}\right)^{\gamma} d\mu_t \tag{23}$$

[34] This allows for the possibility of movement *along* the boundary, since entrepreneurs can still invest while just maintaining the borrowing constraint with strict equality.

$$Y(t) = C(t) + \int_i (c(z,k,b,t) + i(z,k,b,t) + f(i(z,k,b,t),k))\, d\mu_t + [(r_\ell(t) - \psi - r(t))\, A(t) + r(t)N(t)] + q_h(t)\delta_H \tag{24}$$

$$L(t) = \int h(z,k,b,t) d\mu_t \tag{25}$$

$$H_R(t) + H(t) = 1 \tag{26}$$

$$A(t) = M(t) + q_h(t)H_R(t) - \int \mathbb{1}\,(b(t) < 0)\, b(t) d\mu_t = D(t) + \int \mathbb{1}\,(b(t) > 0)\, b(t) d\mu_t + N(t) \tag{27}$$

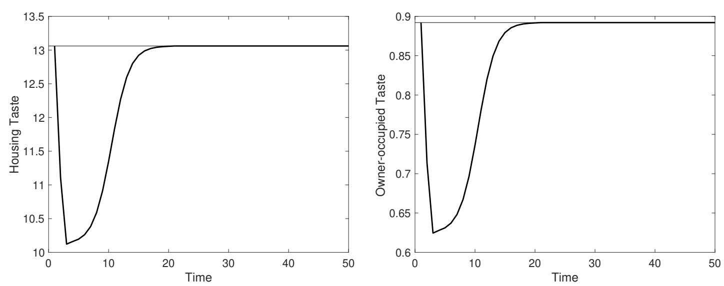
C Model: Parameterization and Housing Taste Shock

This appendix displays the housing taste shock and table of calibrated parameters in the model.

Figure 7: Housing Crisis: Simultaneous shock to Overall Housing Taste and Owner-Occupied Preference

(a) Overall Housing Taste

(b) Owner-Occupied Housing Taste



D Bank balance sheet variables based on Cole and White (2012)

Variables expressed as a percentage of assets unless otherwise noted

- Return on Average Assets: Interest and Noninterest income
- Efficiency Ratio: (noninterest income + net interest margin)/noninterest expense
- Equity Ratio
- Core Deposit Ratio: Non-brokered deposits
- Money Market Ratio
- Security Ratio
- Mortgage Backed Security Ratio: Agency and non-Agency
- Mortgage Ratio: 1-4 family homes
- Home Equity Lines of Credit
- Non-mortgage RE Ratio
- Commercial Loan Ratio
- Consumer Loan Ratio
- Non-Performing Loan Ratio
- Loan Loss Allowance Ratio

E Alternative Explanations for Relationship between House Prices and Young Firm Employment

Does this strategy isolate a lending channel from other potential explanations? Let us take each of the potential rival explanations discussed in Davis and Haltiwanger (2019) and examine whether the interaction considered above is influenced.

E.1 Wealth Effects

An increase (or decrease) in house prices creates wealth effects through two channels. First, higher wealth among potential entrepreneurs creates an appetite for further risk, and may increase the entrepreneur's desire to take on a risky project which may prove to be successful.[35] Second, to the extent that individuals enjoy "being their own boss", a la Hurst and Pugsley (2015), they may be more likely to strike out on their own when they have more wealth associated with higher house prices. While these explanations differ in terms of what "types" of entrepreneurs enter, they both imply an increase in entry and employment in the short run. However, the effect on productivity should differ.

Does variation in bank balance sheets prior to the turn in house prices change the sensitivity of these entrepreneurs to house prices outside of a change in lending practices? It is hard to see how. If the mortgage portfolio of bank balance sheets prior to the peak is somehow correlated with risk taking and self-employment after the peak, it would almost certainly have to come either from general business conditions or lending terms.

E.2 Collateral Effects

However, lending terms themselves can be linked to the value of houses. In particular, homes can be used as collateral by which entrepreneurs and small businesses can gain access to finance. As house prices fall, constraints tighten mechanically. In general, loans provided to small businesses on the basis of housing collateral should be classified as a Home Equity Line of Credit (HELOC). In fact, in the data, I can observe the bank's exposure to such loans, and I create ratios that are then included in the regressions run in the previous section.

Could it be that lending declines simply because housing collateral values decline,

[35] Davis and Haltiwanger (2019) draw out this point citing theoretical work by Khilstrom and Laffont (1979) and more recent empirical work documenting the relationship between wealth and risk aversion in Guiso and Paiella (2008).

and somehow this is correlated with other bank balance sheet variables? It is possible that willingness to grant HELOCs to entrepreneurs is correlated with mortgage exposure, for example. In this case, states with higher mortgage concentrations could have granted more HELOCs pre-crisis and the sensitivity to house prices is due to declining collateral values. However, including a measure of HELOC lending in the regression itself should control for this. Furthermore, this could be an additional effect that might be separable from the credit lending channel in the regression presented above.

E.3 Other Credit Supply Shifts

Other potential channels of house prices through credit supply could be involved. For instance, declines in house prices could indicate declines in future business prospects, and so credit lending is responding endogenously to future business outcomes (left hand side is impacting the right hand side). However, the design of the regression, which uses pre-crisis *residential* bank balance sheet variables should be orthogonal both due to sectoral differences and the timing assumption, since it is plausible that the events post-2007 were surprising to most banks from a 2005 perspective.

Secondly, credit supply shifts could occur that are orthogonal to local business conditions and housing market conditions. Using a method as in Greenstone et al. (2020), which instruments for large bank lending, I can control for such effects in a sample of banks that is largely orthogonal to the one I consider above.

E.4 Non-uniform Consumption Expenditure Response

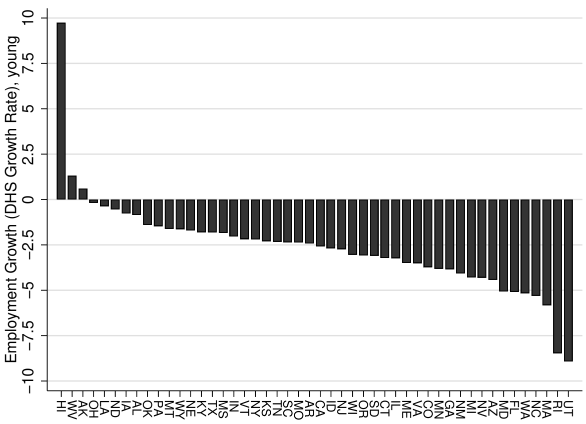
I control for general business conditions and demand using the change in the unemployment rate, as well as the unemployment rate interacted with house price changes. However this may obscure a differential response of young vs. old due to differential demand responses. In short, consumers may cut demand more for young business goods during a recession than for older businesses. I could account for this by performing similar regressions using tradable sectors, rather than the broad set of industries used above.

F Full Bank Balance Sheet Approach

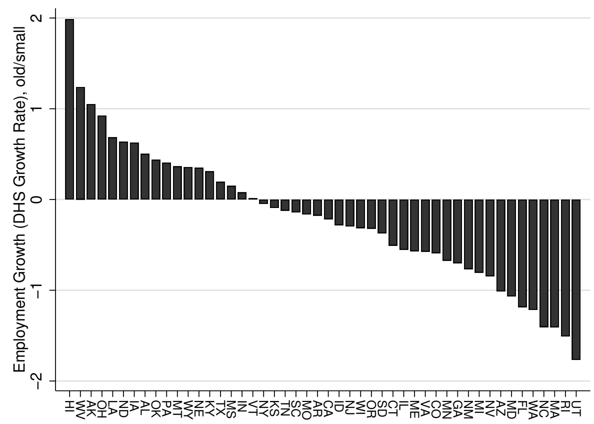
In this appendix, rather than restricting to a single variable or channeling the balance sheet effect through an outcome like bank exit, I turn to a specification where the full set of house price and bank balance sheet interactions is included in the main regression equation. The advantage here is that it captures a broader effect than bank exit and is more comprehensive than relying on the mortgage ratio. However, the output is difficult to interpret, especially in table form.

Instead, I plot the total effect of house prices and their interaction with bank balance sheets for each state. I first plot firm DHS growth rate responses for each individual state to a common house price decline of 5%, which is roughly in line with annual national house price declines during the Great Recession. This isolates the variation due to differences in each state's bank balance sheet conditions, as the house price change and "direct" elasticity to this change are the same across states. Figures 4, 5, and 6 show the impact of the this decline effect on the young, old/small, and old/large groups, respectively.

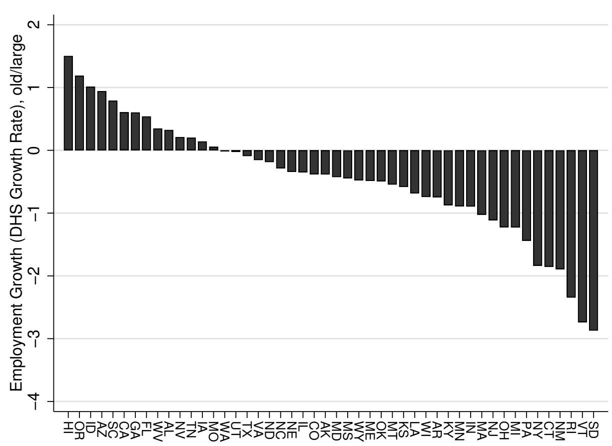
In general, these graphs show substantial impacts of a credit supply channel working through bank balance sheets for all categories of firms. However, they appear qualitatively different. Focusing on the old/small group, the figure shows that although the coefficient on house prices indicates that employment is predicted to fall by 0.2% in response to the 5% decline in house prices, bank balance sheets vary enough to produce notable differences across states: some states' bank balance sheets create an "amplification" effect as predicted employment declines by an additional percentage point, and some state bank balance sheets mitigated the effect of house price declines by as much as 2 percent. Furthermore, some of the states with the largest declines in house prices (Nevada, Arizona, and Florida) seem to have bank balance sheets that contribute to the shock.



(a) Young

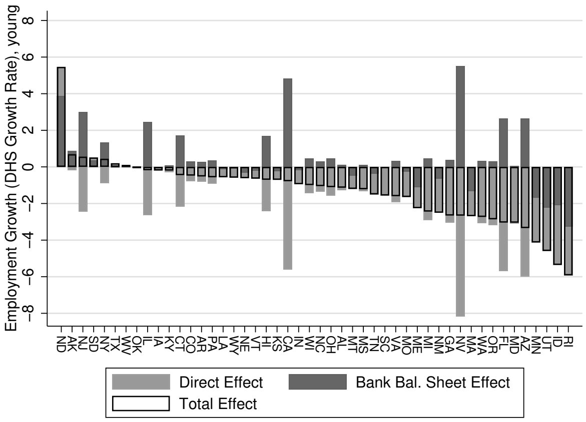


(b) Old/Small

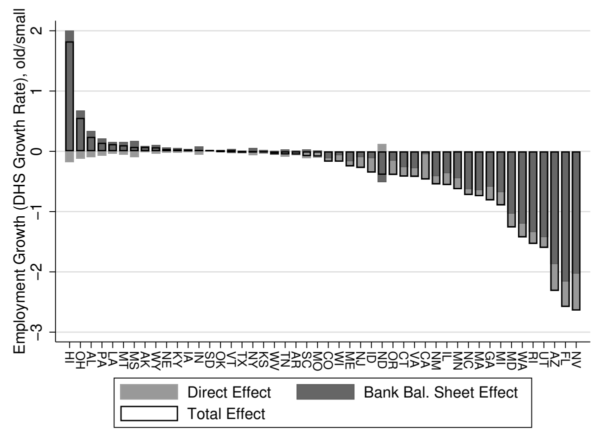


(c) Old/Large

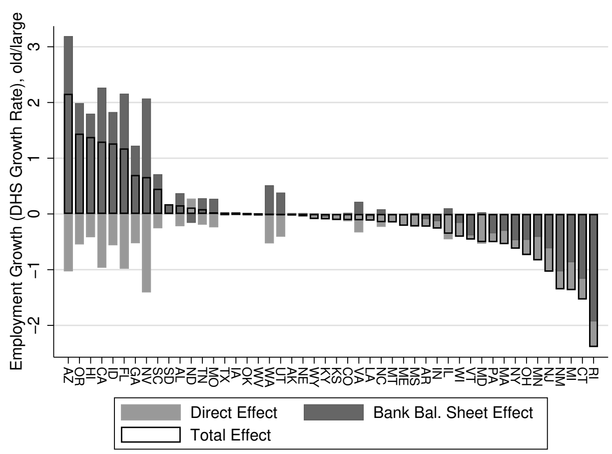
Figure 8: Effect of 5% HPI Change on DHS Employment Growth



(a) Young



(b) Old/Small



(c) Old/Large

Figure 9: Effect of Average State-Level HPI Change on DHS Employment Growth

Among young firms, the range is even larger. The elasticity with respect to house prices creates a decline of about 2.5 percent, but overall predicted responses range from almost a 10 percent increase to an 8 percent decrease. The vast majority of responses are negative, however, with predicted increases in only three states, compared to 18 states with predicted employment increases in response to the decline in house prices for old/small firms.

The response of establishments at old/large firms looks similar to establishments of old/small firms in terms of magnitudes. The 5% decline in house prices generates a predicted decline of 0.5% for old/large firms directly. This means the average effect is slightly lower, but bank effects are generating similar variation to old/small businesses.

To demonstrate further the decomposition of house prices into direct effects and balance sheet effects, I show in Figures 6, 7, and 8 the effect of the change in house prices via the balance sheet interaction terms (called the Bank Balance Sheet effect), the main effect of the house price decline (called the Direct Effect), and the cumulative effect of the interaction and the direct effect of house prices. In these charts, I use the average house price decline in each state rather than a common house price decline, so each state's predicted values are the result of "actual" house price declines in the state and interactions with state bank balance sheets.[36]

From these figures, it is more clear that credit supply, as proxied by local bank balance sheets, seems to be contributing a substantial amount to the overall decline in employment among old/small firms due to house price declines. For young firms, although the overall and local bank credit supply effects of house prices are larger, the effect captured by bank balance sheets appears to have less explanatory power

[36] To establish the significance of the results, I perform F-tests on the joint significance of the sum of all coefficients, properly signed for the direction of the point estimate (that is, I add positive coefficients and subtract negative coefficients). This is a more restrictive test than simply testing the hypothesis that all coefficients are not significantly different from zero. Inclusive of the main effect of house prices, the joint test F-stat is 20.0 (p-value of 0.000) for young, 37.2 (0.000) for old/small, and 26.7 (0.000) for old/large. Considering only the interactions, the joint F-stat is 13.0 (0.000) for young, 33.5 (0.000) for old/small, and 23.5 (0.000) for old/large.

for overall growth in employment among young firms due to house price declines over the Great Recession and subsequent recovery. In particular, for some of the states with the most severe housing collapses (Arizona, California, Florida, and Nevada), bank balance sheets seem to have mitigated their impact on employment. Among establishments at old/large firms, the effect of house prices is largely transmitted through the bank credit supply channel, but again it does not seem to be contributing to declines in the hardest hit states.

G Firm-Level Productivity Analysis

The results in previous sections suggest important differences in the effect of local house price changes and credit conditions on firms depending on their size and age. Another concern for macroeconomists is the effect of the housing crisis on productivity. Are more productive firms more or less likely to experience adverse effects from local house price drops and deteriorating financial conditions? Related literature discusses "cleansing" and "sullying" effects of recessions (e.g. Barlevy, 2002), and Foster et al. (2015) find that the Great Recession did not "cleanse" in the way previous recessions had in the United States. Such effects could matter for aggregate productivity dynamics as entry, exit, and reallocation are potentially important margins for determining productivity growth.

To explore the potential impacts of house price growth on productivity, I use revenue data from the LBD at the firm level. I then create a labor productivity measure using firm revenue divided by total firm employment. This measure captures the existing productivity of the firm as a type of an average revenue product, and and could serve as a proxy for both underlying fundamental total factor productivity and variation in non-labor factor usage, like capital. If house price declines influence firms differently based on their productivity, this could indicate either cleansing effects that mitigate the effects of the housing crisis or sullying effects that amplify the crisis.

However, under the standard assumptions of Cobb-Douglas production and CES utility, there should be no variation in output per unit of labor.[37] Thus, variation in revenue per worker could suggest distortions preventing efficiency from perfect optimization on the part of firms, as Hsieh and Klenow (2009) and the following literature explores. Some financial frictions distort the labor margin, and so variation in the employment response to house prices based on productivity could reflect the presence of financial fricitions. The interpretation of this analysis then depends on whether the theoretical framework implies that output per worker is reflective fundamentals or distortions. We return to these considerations in the theory section as we compare model implications to the following results.[38]

I then use the lag of the natural log of this labor productivity measure as an additional regressor that varies at the firm level in similar regressions to those described previously. Furthermore, I am interested in how the effect of house price growth on employment outcomes varies with productivity, so I include an interaction of the house price growth with the lag labor productivity measure.

$$\Delta Y_{e,t} = \gamma \Delta UR_{c,t} + \gamma \Delta UR_{s,t} + \beta_1 \Delta HPI_{c,t} + \beta_2 LLP_{f,t-1} + \beta_\mathbf{3} \mathbf{\Delta HPI_{c,t}} \times \mathbf{LLP_{f,t-1}} + \alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t} \tag{28}$$

I then run the OLS bank exit regression, including an interaction between bank exit and log labor productivity. This captures differential effects of banking stress across the productivity distribution. Similarly, I consider an additional specification where I include higher order interactions with mortgage shares to capture differential effects of the bank credit supply channel.

About 80% of firms in the LBD have revenue data, so I use propensity score weights in each of the regressions below. I split the results up by young, old, old/small, and old/large according to the definitions used previously. Results from the first

[37]Under these assumptions, average revenue products like output per unit of input are proportional to marginal revenue products, which are in turn equal to the flow cost of the input by first order conditions.

[38]In practice, measures of revenue productivity similar to revenue per worker (like revenue TFP) tend to be positively correlated for underlying fundamentals (Blackwood et al., 2015).

two columns of Table 4 are consistent with previous results, as house prices are highly correlated with employment growth at establishments at young firms, as well as old and old/small firms, in both the OLS and IV specifications. Theory suggests that more productivity firms should grow, so we expect labor productivity to be highly correlated with growth. Columns III and IV in Table 4 shows this is the case, especially for establishments at young firms. Ultimately, our coefficient of interest is the interaction of house prices with productivity. Here we see a key divergence between young and old/small businesses: young firms are impacted by house prices in a similar fashion regardless of productivity, while establishments at old/small firms are disproportionately impacted by house prices if they have low productivity. That is, the negative coefficient on the interaction term suggests a "cleansing" selection mechanism that is present for old/small firms, but not for young firms.

That such an effect does not show up for young firms could then be the result of an offsetting sullying effect. However, on the view that higher productivity firms are more constrained, it is puzzling that more constrained firms are not necessarily more susceptible to house price shocks.

Columns (VI) and (VII) produce some qualifying results to this main finding on productivity. In these specifications, the main effects of financial channels used in previous analysis are not significant for young firms, and thus consistent with the establishment analysis. However, interactions between these indicators, bank exit and the mortgage share of local banks, and labor productivity suggest that whatever influence financial channels have on young firms falls disproportionately on productive firms. Thus, to the extent that the financial channel matters, it disproportionately impacts firms with higher labor productivity. Similarly, higher productivity old/small firms appear to be more impacted by these channels, as the interactions amplify the sign of the main coefficient in the second panel.

Again, interpretation of these results depend on what generates productivity variation. Higher sensitivity to house prices among more productive firms could be the

Table 4: Firm-Level Employment Growth Regressions on House Prices, grouped by firm age/size

	(I)	(II)	(III)	(IV)	(V)
			Young		
△ HPI (OLS)	0.1364		0.1359	0.1359	0.1086
	(0.0215)		(0.0210)	(0.0210)	(0.0255)
△ HPI (IV)		0.1436			
		(0.0421)			
log labor prod. (LLP)	0.2722	0.2680	0.2710	0.2737	0.2749
	(0.0024)	(0.0029)	(0.0027)	(0.0027)	(0.0022)
△ HPI * LLP			-0.0233	-0.0340	0.0550
			(0.0283)	(0.0281)	(0.0373)
Bank Exit				-0.0210	
				(0.0145)	
Bank Exit * LLP				-0.1072	
				(0.0228)	
Mortgage Share					-0.0378
* △ HPI					(0.0223)
Mortgage Share					0.0141
*LLP					(0.0019)
Mortgage Share					0.1452
△ HPI LLP					(0.0282)
N	3,820,000	2,800,000	3,820,000	3,820,000	3,820,000
			Old/Small		
△ HPI (OLS)	0.1047		0.1086	0.1077	0.1247
	(0.0208)		(0.0203)	(0.0201)	(0.0190)
△ HPI (IV)		0.1080			
		(0.0356)			
log labor prod. (LLP)	0.1853	0.1834	0.1820	0.1827	0.1826
	(0.0012)	(0.0015)	(0.0012)	(0.0011)	(0.0011)
△ HPI * LLP			-0.0736	-0.0766	-0.0569
			(0.0179)	(0.0174)	(0.0220)
Bank Exit				-0.0336	
				(0.0095)	
Bank Exit * LLP				-0.0279	
				(0.0145)	
Mortgage Share					0.0195
* △ HPI					(0.0176)
Mortgage Share					0.0029
*LLP					(0.0012)
Mortgage Share					0.0327
△ HPI LLP					(0.0176)
N	12,910,000	8,980,000	12,910,000	12,910,000	12,910,000
			Old/Large		
△ HPI (OLS)	0.0271		0.0243	0.0222	0.0162
	(0.0140)		(0.0140)	(0.0140)	(0.0220)
△ HPI (IV)		0.0089			
		(0.0442)			
log labor prod. (LLP)	0.0132	0.0150	0.0139	0.0129	0.0143
	(0.0006)	(0.0008)	(0.0007)	(0.0008)	(0.0007)
△ HPI * LLP			0.0156	0.0211	0.0334
			(0.0101)	(0.0174)	(0.0115)
Bank Exit				-0.0464	
				(0.0182)	
Bank Exit * LLP				0.0443	
				(0.0150)	
Mortgage Share					-0.0112
* △ HPI					(0.0204)
Mortgage Share					-0.0007
*LLP					(0.0008)
Mortgage Share					0.0217
△ HPI LLP					(0.0134)
N	1,790,000	1,200,000	1,790,000	1,790,000	1,790,000

result of credit channels producing a sullying effect, but it also could be the result of constrained firms experiencing increased tightening while unconstrained firms are less affected.

G.0.1 Firm Productivity in the General Equilibrium Model

Is the model consistent with the evidence on differential effects based on productivity? There are ambiguous effects on productivity within the model, as TFP and labor productivity rises within firm type, but TFP eventually falls overall as selection effects take hold. This eventual decline in TFP appears to be largely down to the collateral channel, as TFP is negatively impacted by the collateral channel and positively impacted by the interest rate channel. Since the collateral channel matters more for young firms in the model, this result is consistent with the weaker cleansing effect found in the data for young firms compared to old/small firms.

However, it is primarily the bank channel in the data that leads to sullying effects, both for young and old/small firms. Thus, the consistency of the model with data is varied. House prices create a disproportionate sullying effect through collateral channels, which primarily affect young firms, but sullying effects appear strongest through the bank channel in the data. Thus, future work could look to allow banking conditions to vary across firms rather than through a single interest rate, providing an additional role for banks to play in misallocation. Further, there is no real role for fundamental productivity to influence labor productivity variation in the model. Recent research has shown that fundamental productivity is closely associated with revenue productivity, suggesting that distortions might not be the whole story. Future research could explore model environments where fundamentals have a greater role to play in productivity variation.

H Additional Empirical Exercises [FOR ONLINE PUBLICATION ONLY]

H.1 Bank-level Exit and Lending Regressions: Muti- and Single-state banks

	All Banks			Single-State Banks			Multi-State Banks		
	Mtg. Del.	Bank Exit		Mtg. Del.	Bank Exit		Mtg. Del.	Bank Exit	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ΔHPI	-0.0189	-0.1219	-0.0723	-0.0192	-0.0862	-0.0563	-0.0164	-0.3540	-0.2166
	(0.0008)	(0.0232)	(0.0229)	(0.0009)	(0.0233)	(0.0230)	(0.0020)	(0.0818)	(0.0798)
MTG_Ratio	0.0012	-0.0049		0.0012	-0.0043		0.0013	-0.0093	
	($3.99e^{-5}$)	(0.0011)		($4.32e^{-5}$)	(0.0011)		(0.0001)	(0.0040)	
ΔHPI*	-0.0067	-0.0287		-0.008	0.0006		0.0007	-0.2441	
MTG_Ratio	(0.0006)	(0.0174)		(0.0007)	(0.0174)		(0.0017)	(0.0658)	
Mortgage			2.101			1.720			1.561
Del. (IV)			(0.4340)			(0.4229)			(1.398)
Year Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	24,912	24,912	24,822	21,248	21,248	21,171	3,664	3,664	3,651
C-D F-Stat			152.9			135.1			35.3

Table 5: Exit Regressions: Bank-level outcomes regressed on House Price Interactions with Bank Balance sheets
Craig-Wald Weak Identification F-test statistic given in for first stage relevance

In this section, I use several bank-level regressions to explore the impact of house prices across different bank types. A key challenge with identification in the main results is identifying appropriate local banking shocks, which required restricting the analysis to relatively small banks that nonetheless made up a significant portion (roughly 30 percent) of small business lending. Banks must be both exposed to local house prices but also transmit those house price shocks to local businesses. In this section, I seek to identify whether the first step, transmission of house prices to banks, holds for the local banks I considered as well as larger banks that span multiple states.

To answer this question, I regress bank exit (related to the first-stage outcome in the second approach in the main results) on house price shocks and interactions with 2005 mortgage shares (similar to the first approach in the main results). The house prices are bank-specific in that that are constructed based on bank exposure to local house prices through deposits. I take data from the FDIC on branch level deposits to construct a composite house price shock for each bank that is a deposit-weighted average of county-level house prices associated with the branch. I run a linear regression

$$BE_{b,t} = \iota_{b,t}^{multi} + \gamma \Delta UR_{b,t} + \beta_1 \Delta HPI_{b,t} + \beta_2 MTG_{b,2005} + \beta_3 \Delta HPI_{b,t} \times MTG_{b,2005} + \delta_t + \epsilon_{b,t}$$

$BE_{b,t}$ is a dummy variable that indicates if the bank b exited in time t. Unemployment is a bank-specific deposit-weighted average as with house prices, and δ_t is a time effect.[39] When running on the full sample, I also control for multi-state vs. single-state. In column (2) of table 6, I find a marginally significant effect of house price interactions with mortgages on bank exit, with positive house price shocks associated with lower bank exit and the interaction effect amplifying the effect of house prices. Interestingly, this is primarily due to multi-state banks, as seen by the strongly significant effect in column (8), rather than single-state banks, shown in column (5).

To further explore how interactions of house prices with additional bank balance sheet variables affect exit, I use a two-stage approach, with mortgage delinquencies serving as the intermediate outcome. Theoretically, we expect bank portfolio choices to interact with house prices via deterioration in asset performance. One such outcome would be mortgage performance, which should then affect bank solvency and survival. As evidence of pre-crisis portfolio variables' predictive value in the first stage, I include a simplified regression with just house prices interacted with mortgage shares in 2005 as a regressor in columns (1), (4), and (7) in table 6, where the

[39] I do not use fixed effects since some banks span multiple geographies and the outcome variable does not permit for multiple observations of the outcome of 1, since exit is an absorbing state.

outcome is the share of assets that are delinquent (90+ days overdue plus nonperforming loans) mortgages:

$$MD_{b,t} = \iota_{b,t}^{multi} + \gamma \Delta UR_{b,t} + \beta_1 \Delta HPI_{b,t} + \beta_2 MTG_{b,2005} + \beta_3 \Delta HPI_{b,t} \times MTG_{b,2005} + \delta_t + \epsilon_{b,t}$$

These regressions show a significant relationships between house prices and mortgage delinquency, and in particular house price interactions with pre-crisis mortgage shares and delinquency. Across these specifications, increased house prices are associated with lower mortgage delinquency. Likewise, for the total sample and small banks, interactions of house prices with pre-crisis mortgage shares negatively predict delinquency ratios. Thus, having more exposure to house price shocks amplifies the impact of house prices on mortgage delinquency shares. However, for large banks, the results are insignificant and positive. This suggests that the relevant mechanism connecting house price exposure to bank performance may be different for different size banks. In particular, liabilities might be impacted as well as assets due to house price changes.

Predicted mortgage delinquency $\widehat{MD}$ using a full set of interactions between house price shocks and bank balance sheets are then considered as a regressor in the exit regressions:

$$BE_{b,t} = \iota_{b,t}^{multi} + \gamma \Delta UR_{b,t} + \beta_1 \Delta HPI_{b,t} + \widehat{MD}_{b,t} + \delta_t + \epsilon_{b,t}$$

Columns (3), (6), and (9) of table 6 present these results. Overall, bank exit is positively associated with predicted mortgage delinquencies, as we would expect. The magnitude for both single and multi-state banks are similar, although only significant for single-state banks.

I then consider commercial loan balances as an outcome. Some caution is to be used with such an outcome, as loan balances can change due to restriction of new

	All Banks			Single-State Banks			Multi-State Banks		
	Mtg. Del.	Commercial Loans		Mtg. Del.	Commercial Loans		Mtg. Del.	Commercial Loans	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
HPI	-1.63e^{-5}	0.0013	0.0006	-1.65e^{-5}	0.0014	0.0005	-1.46e^{-5}	0.0007	0.0004
	(7.80e^{-7})	(8.62e^{-5})	(0.0002)	(8.82e^{-7})	(7.89e^{-5})	(0.0004)	(1.93e^{-6})	(0.0818)	(0.0004)
HPI*	-0.0010	0.0395		-0.0007	0.0395		-0.0043	0.1175	
MTG_Ratio	(0.0002)	(0.0189)		(0.0002)	(0.0161)		(0.0006)	(0.1200)	
Mortgage			-42.85			-45.77			-15.12
Del. (IV)			(8.752)			(8.643)			(23.01)
Year Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm Effect	Y	Y	Y	Y	Y	Y	Y	Y	Y
N	24,244	24,016	24,008	20,601	20,418	20,418	3,532	3,489	3,481
C-D F-Stat			12.7			9.1			6.0

Table 6: Commercial Lending Regressions: Bank-level outcomes regressed on House Price Interactions with Bank Balance sheets.
Craig-Wald Weak Identification F-test statistic given in for first stage relevance.

lending or recalling loans (what I hope to capture in these regressions) as well as borrowers paying off loans. In these regressions, I use a standard diff-in-diff approach by controlling for bank fixed effects. The regressions are of the following form:

$$Y_{b,t} = \iota_{b,t}^{multi} + \gamma UR_{b,t} + \beta_1 HPI_{b,t} + \beta_2 HPI_{b,t} \times MTG_{b,2005} + \lambda_b + \delta_t + \epsilon_{b,t}$$

Where $Y_{b,t}$ is bank outcome (either the log of commercial lending balances or mortgage delinquency rate) and λ_b is the bank fixed effect. I find significant coefficients of mortgage interactions in the mortgage delinquency regressions for all bank types. Generally speaking, commercial lending is positively associated with house price interactions with bank mortgages, and negatively related to predicted mortgage delinquency, as suggested by theory. However, results for multi-state banks are generally insignificant. In the case of column (8), the interaction of house prices and mortgages has a larger coefficient for multi-state banks than smaller banks, albeit an insignificant one.

In general, these results point to associations between constructed house price shocks using deposit shares and bank performance. At a high level, this analysis suggests that interactions of these house prices with pre-crisis bank balance sheets does amplify house prices' impact on bank health for banks of all sizes, although the mechanisms may differ. Overall lending outcomes are more mixed, but generally align with the exit analysis.

H.2 Model Fit and Relevance Statistics

In this section, I present the R^2 measures for the regressions run in the main body of the text, using adjusted and centered measures where appropriate. Furthermore, I report first-stage Kleiberggen-Paap (K-P) cluster-robust first-stage statistics for all instruments, as well as the Angrist-Pischke (A-P) statistics for relevance of each instrumented variable when instrumenting for more than one variable.

	Total	Young	Old	Old/Small	Old/Large
OLS					
Adjusted R^2	0.040	0.013	0.030	0.040	0.021
N	27,230,000	7,810,000	19,420,000	16,510,000	2,910,000
IV					
Centered R^2	0.005	0.002	0.021	0.031	0.003
N	19,000,000	5,670,000	13,330,000	11,430,000	1,900,000

Table 7: R^2 of Regressions in Table 1

	Young	Old	Old/Small	Old/Large
OLS				
Adjusted R^2	0.013	0.030	0.040	0.021
N	7,810,000	19,420,000	16,510,000	2,910,000
Total IV				
Centered R^2	0.002	0.021	0.031	0.003
N	5,670,000	13,330,000	11,430,000	1,900,000

Table 8: R^2 of Regressions in Table 2

	Young	Old	Old/Small	Old/Large
OLS				
Adjusted R^2	0.013	0.030	0.040	0.021
N	7,810,000	19,420,000	16,510,000	2,910,000
Instrumented HPI				
Centered R^2	0.002	0.021	0.031	0.003
N	5,670,000	13,330,000	11,430,000	1,900,000
Instrumented Bank Exit				
Centered R^2	0.002	0.021	0.031	0.003
N	7,810,000	19,420,000	16,510,000	2,910,000
Instrumented HPI and Bank Exit				
Centered R^2	0.002	0.021	0.031	0.003
N	5,670,000	13,330,000	11,430,000	1,900,000

Table 9: R^2 of Regressions in Table 3

	Total	Young	Old	Old/Small	Old/Large
IV					
F-Stat	101.6	100.2	100.4	96.7	121.6
N	19,000,000	5,670,000	13,330,000	11,430,000	1,900,000

Table 10: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Regressions in Table 1

	Young	Old	Old/Small	Old/Large
Total IV				
K-P F-stat	13.7	14.7	14.5	16.0
HPI A-P F-stat	49.2	51.2	54.3	36.1
HPI*MTG_RATIO A-P F-stat	27.3	26.5	29.0	16.9
N	5,670,000	13,330,000	11,430,000	1,900,000

Table 11: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Regressions in Table 2

	Young	Old	Old/Small	Old/Large
Instrumented HPI				
F-stat	101.0	99.9	96.3	121.1
N	5,670,000	13,330,000	11,430,000	1,900,000
Instrumented Bank Exit				
K-P F-stat	22.4	15.6	15.8	15.7
N	7,810,000	13,330,000	16,510,000	2,910,000
K-P F-stat	9.7	9.4	8.9	14.7
$\widehat{HPI}$ A-P F-stat	17.7	14.1	14.5	12.0
$\widehat{BE}$ A-P F-stat	9.9	9.6	9.0	14.7
N	5,670,000	13,330,000	11,430,000	1,900,000

Table 12: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Regressions in Table 3

H.3 Tradable Sector Results

Restricting the sample of industries under consideration to those in the tradable sector, as defined by Mian and Sufi (2014), I consider the effect of house prices on employment outcomes, splitting by age and size as in the main text. Furthermore, I consider the mortgage share and bank exit approaches.

I find that house prices have significant effects on young businesses in particular, even among "tradable" industries. There is also an impact of house prices on old/small businesses, but this is not robust to instrumenting for house prices. The bank exit approach does indicate a significant impact of the bank balance sheet channel on old/small businesses for the bank balance sheet channel. However, there does not appear to be a significant impact of the interaction of mortgages with house prices.

In addition, I provide model fit and first-stage relevance tests in tables below.

	Total	Young	Old	Old/Small	Old/Large
OLS					
$\triangle$ HPI	0.0856	0.2283	0.0458	0.0524	-0.0513
	(0.0280)	(0.0676)	(0.0253)	(0.0273)	(0.0482)
N	1,250,000	230,000	1,030,000	880,000	150,000
IV					
$\triangle$ HPI	0.1585	0.4431	0.0310	0.0345	-0.1850
	(0.0588)	(0.1713)	(0.0576)	(0.0642)	(0.1267)
N	880,000	160,000	710,000	620,000	100,000

Table 13: Employment Growth Regressions on House Prices, grouped by firm age/size

	Young	Old	Old/Small	Old/Large
OLS				
△ HPI	0.3921	0.1592	0.1632	0.0456
	(0.1060)	(0.0406)	(0.0444)	(0.0707)
△ HPI*	0.1809	0.1344	0.1308	0.1166
MTG_RATIO	(0.0871)	(0.0344)	(0.0374)	(0.0595)
N	230,000	1,030,000	880,000	150,000
Total IV				
△ HPI	0.3070	0.1915	0.1551	0.1220
	(0.3411)	(0.1289)	(0.1425)	(0.3097)
△ HPI*	-0.1276	0.1664	0.1285	0.2914
MTG_RATIO	(0.2998)	(0.0969)	(0.1045)	(0.2428)
N	160,000	710,000	620,000	100,000

Table 14: Employment Growth Regressions on House Price/Mortgage Share Interactions by Firm Age/Size

	Young	Old	Old/Small	Old/Large
OLS				
△ HPI	0.2395	0.0457	0.0520	-0.0507
	(0.0696)	(0.0254)	(0.0273)	(0.0481)
Bank Exit	0.2211	-0.0019	-0.0093	0.0219
	(0.1126)	(0.0217)	(0.0241)	(0.0524)
N	230,000	1,050,000	880,000	150,000
Instrumented HPI				
$\triangle\widehat{HPI}$	0.4429	0.0309	0.0344	-0.1842
	(0.1686)	(0.0577)	(0.0644)	(0.1274)
Bank Exit	0.2244	-0.0095	-0.0196	0.0283
	(0.1422)	(0.0241)	(0.0273)	(0.0608)
N	160,000	710,000	620,000	100,000
Instrumented Bank Exit				
△ HPI	0.2084	0.0381	0.0453	-0.0609
	(0.0672)	(0.0245)	(0.0263)	(0.0493)
$\widehat{BE}$	-0.3945	-0.2225	-0.1952	-0.3459
	(0.3275)	(0.1254)	(0.1378)	(0.2344)
N	230,000	1,030,000	880,000	150,000
Instrumented HPI and Bank Exit				
$\triangle\widehat{HPI}$	0.4822	0.0546	0.0555	-0.1319
	(0.1514)	(0.0494)	(0.0559)	(0.1301)
$\widehat{BE}$	0.3522	-0.0648	-0.2247	0.6886
	(0.5474)	(0.1766)	(0.1943)	(0.3300)
N	160,000	710,000	620,000	100,000

Table 15: Employment Growth Regressions on Bank Exit by Firm Age/Size

	Total	Young	Old	Old/Small	Old/Large
OLS					
Adjusted R^2	0.052	0.015	0.036	0.048	0.017
N	1,250,000	230,000	1,030,000	880,000	150,000
IV					
Centered R^2	0.008	0.002	0.023	0.035	0.002
N	880,000	160,000	710,000	620,000	100,000

Table 16: R^2 of Regressions in Table 13

	Young	Old	Old/Small	Old/Large
OLS				
Adjusted R^2	0.016	0.036	0.048	0.017
N	230,000	1,030,000	880,000	150,000
Total IV				
Centered R^2	0.002		0.035	0.002
N	160,000	710,000	620,000	100,000

Table 17: R^2 of Regressions in Table 14

	Young	Old	Old/Small	Old/Large
OLS				
Adjusted R^2	0.015	0.036	0.048	0.017
N	240,000	1,030,000	880,000	150,000
Instrumented HPI				
Centered R^2	0.002		0.035	0.002
N	160,000		620,000	100,000
Instrumented Bank Exit				
Centered R^2	0.002	0.023	0.034	0.001
N	230,000	1,030,000	880,000	150,000
Instrumented HPI and Bank Exit				
Centered R^2	0.002		0.035	0.001
N	160,000	710,000	620,000	100,000

Table 18: R^2 of Regressions in Table 15

	Total	Young	Old	Old/Small	Old/Large
IV					
F-Stat	99.1	130.5	92.6	91.0	97.0
N	880,000	160,000	710,000	620,000	100,000

Table 19: First Stage Kleibergen-Paap rk Wald F-stat of Regressions in Table 13

	Young	Old	Old/Small	Old/Large
Total IV				
K-P F-stat	12.9	13.3	12.7	17.6
HPI A-P F-stat	65.3	87.5	95.6	42.4
HPI*MTG_RATIO A-P F-stat	48.3	43.8	46.8	28.9
N	160,000	710,000	620,000	100,000

Table 20: First Stage Kleibergen-Paap rk Wald and Angrist Pischke F-stats of Regressions in Table 14

	Young	Old	Old/Small	Old/Large
Instrumented HPI				
F-stat	133.8	90.1	88.7	94.6
N	160,000	710,000	620,000	100,000
Instrumented Bank Exit				
K-P F-stat	22.2	16.7	15.7	26.6
N	230,000	1,030,000	880,000	150,000
Total IV				
K-P F-stat	8.0	9.0	8.2	17.2
$\widehat{HPI}$ A-P F-stat	18.9	11.9	12.5	9.4
$\widehat{BE}$ A-P F-stat	8.7	9.1	8.4	16.8
N	160,000	710,000	620,000	100,000

Table 21: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Regressions in Table 15

H.4 Alternative Timing

These results reflect a change in timing for regressors. Since employment is recorded on March 12 of the calendar year for the LBD, and house prices are annual, there is the potential for mismatch in timing. In the main text, growth from house prices from year t-1 to t is used as a regressor for growth From March 12 in year t-1 to March 12 in t.

Table 22: Establishment-Level Employment Growth Regressions on House Prices, grouped by firm age/size: Q1 Timing

	Total	Young	Old	Old/Small	Old/Large
OLS					
△ HPI	0.1396	0.1706	0.1072	0.1048	0.0412
	(0.0249)	(0.0333)	(0.0210)	(0.0248)	(0.0129)
N	27,230,000	7,810,000	19,420,000	16,510,000	2,910,000
IV					
△ HPI	0.2758	0.2429	0.2232	0.2077	0.0905
	(0.0412)	(0.0622)	(0.0424)	(0.0496)	(0.0449)
N	19,000,000	5,670,000	13,330,000	11,430,000	1,900,000

Table 23: Establishment-Level Employment Growth Regressions on House Prices, grouped by firm age/size: Synthetic Timing

	Total	Young	Old	Old/Small	Old/Large
OLS					
△ HPI	0.1524	0.1183	0.1457	0.1393	0.1191
	(0.0200)	(0.0345)	(0.0171)	(0.0190)	(0.0170)
N	27,220,000	7,810,000	19,420,000	16,510,000	2,910,000
IV					
△ HPI	0.2979	0.2533	0.2435	0.2077	0.1058
	(0.0696)	(0.0782)	(0.0682)	(0.0496)	(0.0531)
N	19,000,000	5,670,000	13,330,000	11,430,000	1,900,000

Since this house price is will reflect more mid-year house price growth, I use unemployment in quarter 2 as the additional regressor (and first stage regressor for house prices). So, both unemployment and house prices could be capturing changes in employment conditions after the measurement of employment. However, using an earlier time for house prices could miss developments in housing markets. Likewise, using earlier unemployment timing could reduce the explanatory power of unemployment for house prices.

Table 24: Establishment-Level Employment Growth Regressions on House Price/Mortgage Share Interactions by Firm Age/Size: Q1 Timing

	Young	Old	Old/Small	Old/Large
OLS				
△ HPI	0.2577	0.1550	0.1573	0.0344*
	(0.0323)	(0.0132)	(0.0152)	(0.0184)
△ HPI*	0.1080	0.0623	0.0677	-0.0094
MTG_RATIO	(0.0319)	(0.0167)	(0.0208)	(0.0175)
N	7,810,000	19,420,000	16,510,000	2,910,000
Total IV				
△ HPI	0.1243	0.3008	0.2875	0.0477
	(0.1009)	(0.0810)	(0.0938)	(0.0860)
△ HPI*	-0.1426	0.1018	0.1023	-0.0466
MTG_RATIO	(0.1018)	(0.0628)	(0.0757)	(0.0724)
N	5,670,000	13,330,000	11,430,000	1,900,000

To explore the effect of these timing issues, I present two sets of results. First I use unemployment in quarter 1 rather than quarter 2. Second I used quarter 1 unemployment and a "synthetic" house price that is a mixture of house prices from year t and t-1:

$$synHPI_t = 0.75 * HPI_{t-1} + 0.25 * HPI_t \tag{29}$$

The results are similar along most dimensions to the main results, although the outsize influence on young firms of house prices appears a bit weaker.

Table 25: Establishment-Level Employment Growth Regressions on House Price/Mortgage Share Interactions by Firm Age/Size: Synthetic Timing

	Young	Old	Old/Small	Old/Large
OLS				
△ HPI	0.0298	0.1415	0.1368	0.0663
	(0.0419)	(0.0224)	(0.0252)	(0.0184)
△ HPI*	-0.1119	-0.0055	-0.0033	-0.0736
MTG_RATIO	(0.0303)	(0.0145)	(0.0156)	(0.0203)
N	7,810,000	19,420,000	16,510,000	2,910,000
Total IV				
△ HPI	0.2777*	0.4727	0.4687	0.0379
	(0.1509)	(0.0995)	(0.1153)	(0.1224)
△ HPI*	-0.0658	0.3153	0.3353	-0.1002
MTG_RATIO	(0.1544)	(0.0976)	(0.1077)	(0.1359)
N	5,670,000	13,330,000	11,430,000	1,900,000

Table 26: Establishment-Level Employment Growth Regressions on Bank Exit by Firm Age/Size: Q1 Timing

	Young	Old	Old/Small	Old/Large
OLS				
$\triangle$ HPI	0.1719	0.1067	0.1037	0.0417
	(0.0333)	(0.0213)	(0.0252)	(0.0132)
Bank Exit	0.0070	-0.0355	-0.0402	-0.0258
	(0.0269)	(0.0115)	(0.0120)	(0.0184)
N	7,610,000	18,890,000	16,050,000	2,830,000
Instrumented HPI				
$\triangle \widehat{HPI}$	0.2355	0.2210	0.2054	0.0842
	(0.0620)	(0.0415)	(0.0489)	(0.0455)
Bank Exit	-0.0134	-0.0287	-0.0336	-0.0244
	(0.0295)	(0.0118)	(0.0128)	(0.0220)
N	5,540,000	12,990,000	11,140,000	1,850,000
Instrumented Bank Exit				
$\triangle$ HPI	0.1682	0.1009	0.0971	0.0410
	(0.0347)	(0.0221)	(0.0264)	(0.0130)
$\widehat{BE}$	-0.0795	-0.1883	-0.2006	-0.0540
	(0.1340)	(0.0673)	(0.0786)	(0.0814)
N	7,610,000	18,890,000	16,050,000	2,830,000
Instrumented HPI and Bank Exit				
$\triangle \widehat{HPI}$	0.1933	0.1468	0.1345	0.0059
	(0.0503)	(0.0332)	(0.0402)	(0.0448)
$\widehat{BE}$	-0.1121	-0.3464	-0.3786	-0.2953
	(0.1216)	(0.0630)	(0.0694)	(0.0834)
N	5,540,000	12,990,000	11,140,000	1,850,000

Table 27: Establishment-Level Employment Growth Regressions on Bank Exit by Firm Age/Size: Synthetic Timing

	Young	Old	Old/Small	Old/Large
OLS				
$\triangle$ HPI	0.1207	0.1431	0.1351	0.1194
	(0.0337)	(0.176)	(0.0197)	(0.0176)
Bank Exit	0.0281	-0.0010	-0.0163	-0.0033
	(0.0267)	(0.0109)	(0.0118)	(0.0179)
N	7,600,000	18,880,000	16,050,000	2,830,000
Instrumented HPI				
$\triangle\widehat{HPI}$	0.2518	0.2463	0.2262	0.1015
	(0.0818)	(0.0710)	(0.0768)	(0.0554)
Bank Exit	0.0439	0.0172	0.0078	-0.0043
	(0.0443)	(0.0222)	(0.0248)	(0.0264)
N	5,540,000	12,990,000	11,140,000	1,850,000
Instrumented Bank Exit				
$\triangle$ HPI	0.1176	0.1418	0.1360	0.0972
	(0.0340)	(0.0186)	(0.0209)	(0.0201)
$\widehat{BE}$	0.0153	-0.0159	-0.0123	-0.1098
	(0.1428)	(0.0436)	(0.0449)	(0.0552)
N	7,600,000	18,880,000	16,050,000	2,830,000
Instrumented HPI and Bank Exit				
$\triangle\widehat{HPI}$	0.1520	0.1576	0.1325	0.0153
	(0.0579)	(0.0506)	(0.0561)	(0.0563)
$\widehat{BE}$	-0.1731	-0.3611	-0.4029	-0.2901
	(0.1488)	(0.0676)	(0.0748)	(0.0847)
N	5,540,000	12,990,000	11,140,000	1,850,000

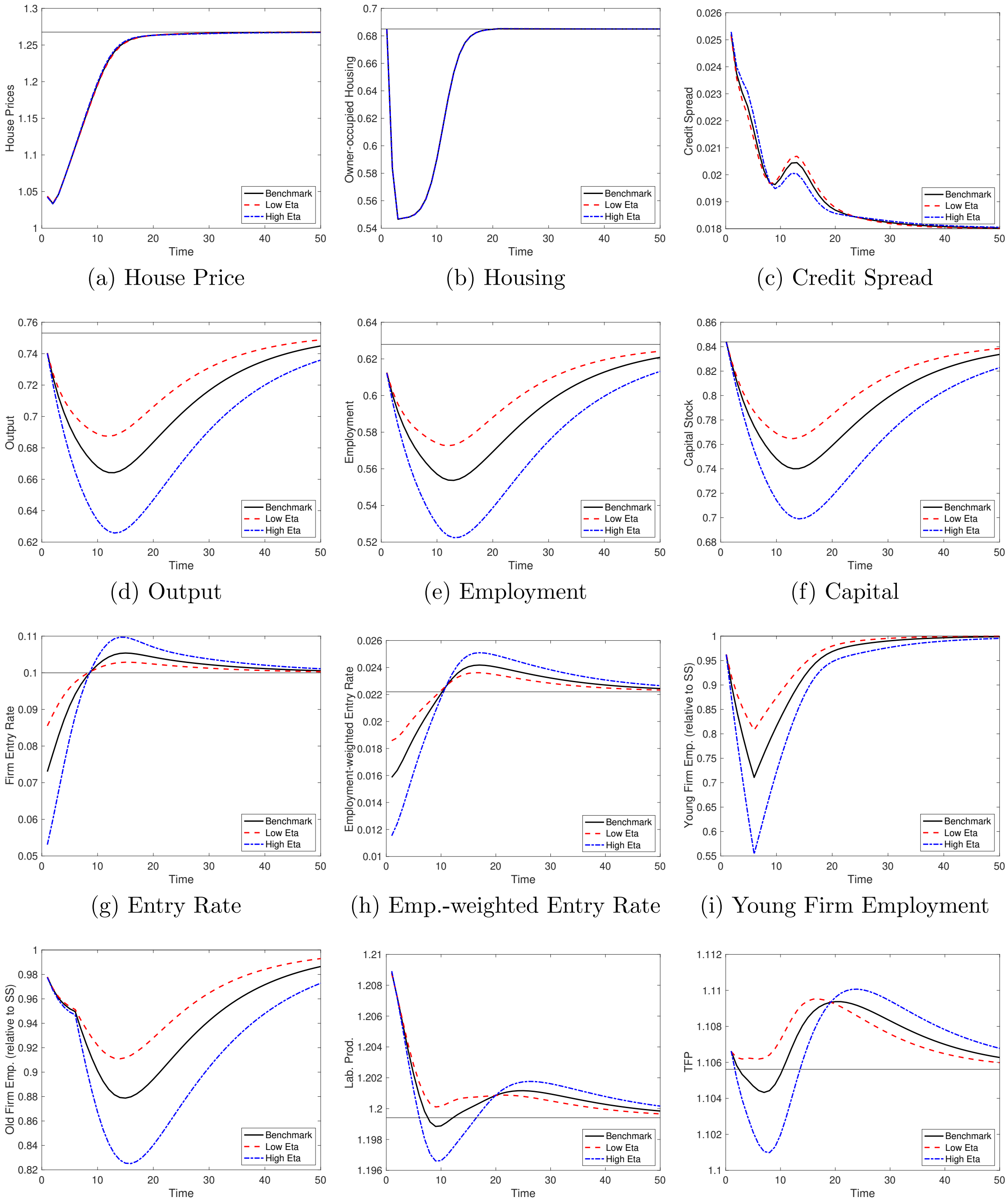
I Elasticity of Entry [FOR ONLINE PUBLICATION ONLY]

In this section, I explore the response of the economy under different values of η, the elasticity of entry in the Hopenhayn model. I consider proportional changes–halving and doubling the elasticity. Crucially, I use the same shock to ν_h and ϵ_h as in the original exercise, which in turn means that house prices and interest rates can react differently than under the original shock. In the end, responses of these prices are similar, if not identical.

I display the main results of the two experiments in comparison to the crisis under the original parameterization. Clearly increasing or decreasing this elasticity leads to very different responses of entry, as seen in the figure. This translates to substantially different aggregate outcomes, with higher elasticities translating to deeper, more persistent recessions. The greater depth of the recession is intuitive, as entry responds more and thus output and employment fall more. However, in response to improving conditions, it is also be the case that entry "overshoots" more and contributes to the recovery. However, this second effect is not very large and does not dominate the lasting impacts of the recession as it takes much longer for productive capacity to recover.

This is in part due to lower productivity that results from fewer relatively high productivity firms entering with higher elasticities. Lower elasticities can result in a sustained *increase* in TFP as "cleansing" works through low productivity firm exit, but the lack of an influence on entrants limits the "sullying" effect. The sullying effect is more substantial and lasts much longer under higher elasticities, where TFP drops severely and remains low for an extended period. Further, the drop in entry has implications for capital accumulation as well, and so labor productivity falls notably under high elasticities, while it rises and remains elevated in the low-elasticity regime.

Clearly this is a crucial parameter for determining quantitative outcomes for the



(a) House Price (b) Housing (c) Credit Spread

(d) Output (e) Employment (f) Capital

(g) Entry Rate (h) Emp.-weighted Entry Rate (i) Young Firm Employment

(j) Old Firm Employment (k) Labor Productivity (l) TFP

Figure 10: Housing Crisis: Aggregate Impulse Responses Under Alternative Entry Elasticities

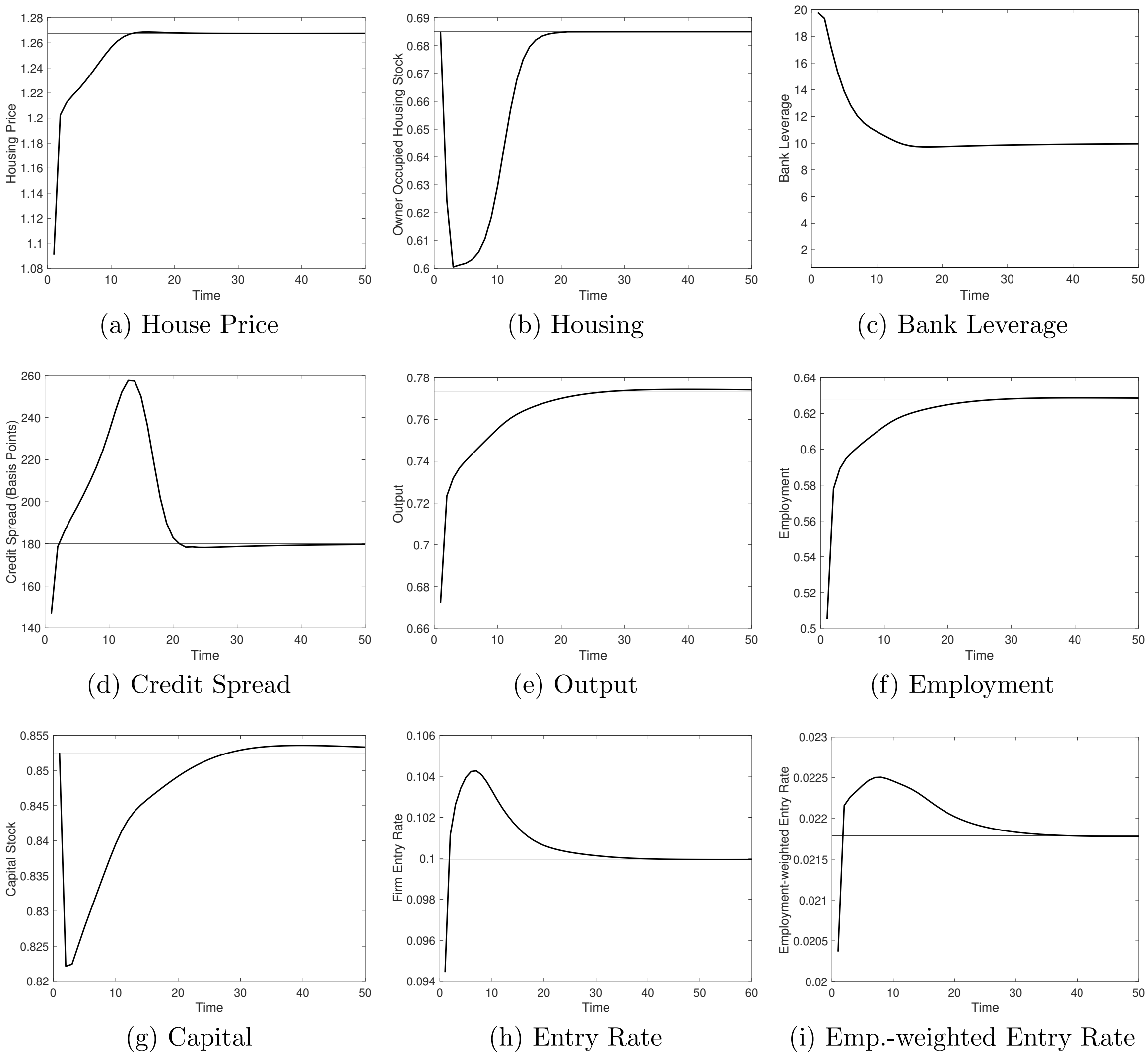
aggregate economy, both in terms of recession severity and persistence. In reality, this elastcity is likely governed by potentially endogenous determinants of outside options, risk aversion, and entrepreneurial expectations. I leave investigation into this matter to future research.

J Closed Economy [FOR ONLINE PUBLICATION ONLY]

In the closed economy version, the result of the same shock to housing preferences is similar along many dimensions, although the overall crisis is less severe–house prices do not fall as much and the owner-occupied housing stock drops by less. The financial crisis is similar in that leverage rises sharply, but rather than manifesting itself in rising credit spreads, *both* deposit rates and lending rates rise (unrealistically) by over 10 basis points, while the spread falls. Although rates drops quickly after the initial year, spreads then rise and remain elevated for some time after, sustaining the financial crisis for a longer time. This extreme tightening in credit conditions linked to the dramatic effect on existing businesses. While entry falls slightly at the onset, existing businesses are hit hard enough and forced to exit at such a high rate that the entry rate actually rises within the first few years. Ultimately, this implies a sharper initial drop in output and employment, but a quicker recovery. Thus, the rigidity in deposit rates seems to be an important driver of macroeconomic patterns, both in terms of initial impact and persistence. Likewise, it matters greatly for cleansing and sullying effects, as the large increase in interest rates generates a large increase in (labor and total factor) productivity as the cleansing effect dominates.[40]

In some ways, these results are reasonable given our empirical findings: older businesses appear to be more affected by financial distress, in this case higher interest rates. Thus, under extreme credit tightening, the financial channel swamps the collat-

[40]Also, note the grid is somewhat sparser in this version of the model for computational reasons, although there is no reason to believe this is the key driver of the results highlighted.



(a) House Price (b) Housing (c) Bank Leverage

(d) Credit Spread (e) Output (f) Employment

(g) Capital (h) Entry Rate (i) Emp.-weighted Entry Rate

Figure 11: Housing Crisis: Aggregate Impulse Responses (Closed Economy)

eral channel and the impact on entry *rates* is diminished, and in this case eliminated. It is also important to keep in mind that there is not role for central bank policy in easing credit conditions through monetary policy and its influence over real interest rates, as the model neither incorporates sticky prices or any other mechanism for monetary non-neutrality. Additionally, there is no role for the fiscal authority in the model to assist financial institutions, which also would lead to a reduced tightening in credit conditions faced by firms. As such, one could consider the open-economy version of the model as an illustration of dynamics under monetary policy that keeps deposit rates constant, but does not lower them below their initial level.[41] Without such a policy, credit conditions would deteriorate much more. Further, one can think of the version of the model where credit spreads are constant as an extreme policy where support for credit institutions eliminates the pressure on interest rates. Clearly, such a policy is unlikely to be feasible, but it provides a bound for the ability of monetary/fiscal authorities to impact outcomes by easing credit conditions.

K Guess and Verify Solution to the Banking problem [FOR ONLINE PUBLICATION ONLY]

Note that ℓ, m, and H_R are state variables, and thus the relevant choice variables for the bank are $\dot{\ell}$, $\dot{m}$, and $\dot{H}_R$, along with $\dot{d} = \frac{d}{dt}\left(q_h h_R + \ell + m\right) - \dot{n}$. So the Bellman equation can be written as (denoting $V_x = V_x(\ell, m, h_R, d)$:

$$(\rho+\sigma)\, V\left(\ell, m, h_R, d\right) = \max_{\dot{l}, \dot{m} \dot{H}_R} \left(1 - e^{-\sigma}\right) n + V_\ell \dot{\ell} + V_m \dot{m} + V_H \dot{h_R} \tag{30}$$

$$+V_d\left(\dot{q_h} H_R + q_h \dot{h_R} + \dot{\ell} + \dot{m} - \left(\frac{\dot{q_h} + R_h - \delta_h}{q_h} - \psi\right) q_h h_R - \left(r_\ell - \psi\right)\ell - \left(r_m - \psi\right) m + rd\right) + V_t$$

$$+\lambda\left(V\left(\ell, m, h_R, d\right) - \theta\left(q_h h_R + \ell + m\right)\right)$$

[41] While not a zero lower bound, it is similar in respect to a central bank constrained by a lower bound in that deposit rates are "stuck" at their initial level.

The first order conditions of this problem can be combined to show that rates of return are equalized across assets, so that there is a single rate of return R_a:

$$R_a = r_\ell = r_m = \frac{\dot{q_h} + R_h - \delta_h}{q_h} \tag{31}$$

And thus the gross return on total assets can be written as $(R_a - \psi)\, a = \left(\frac{\dot{q_h}+R_h-\delta_h}{q_h} - \psi\right) q_h h_R + (r_\ell - \psi)\,\ell + (r_m - \psi)\, m$.

We can also show the following holds for $x \in \{H, \ell, m\}$:

$$(R_a - \psi - r)\, V_x = \lambda\theta \tag{32}$$

Thus, we see that the spread $(R_a - r)$ is strictly positive, but the spread is greater than ψ if and only if $\lambda > 0$, i.e. when the constraint binds. The constraint is what generates the spread between the lending and the deposit rate.

Guessing the value function is linear in deposits and loans, so $V = \gamma_{at}a + \gamma_{dt}d$ where γ_{at} and γ_{dt} are time-varying constants, with appropriate substitution of constraints we can rewrite the Bellman equation as:

$$(\rho + \sigma)\, V(a, d, t) = \max_{\dot{a}} \left(1 - e^{-\sigma}\right)(a - d) + \gamma_{at}\dot{a} + \gamma_{dt}\left(\dot{a} - (R_a - \psi)\, a + rd\right) + \dot{\gamma_{at}}a + \dot{\gamma_{dt}}d + \lambda\left(\gamma_{at}a + \gamma_{dt}d - \theta a\right) \tag{33}$$

Where γ_{xt} is the time-derivative of the constant associated with the state variable x. Recognizing that first order conditions imply $\gamma_{at} = -\gamma_{dt}$, and likewise $\frac{d}{dt}(\gamma_{at} - \gamma_{dt}) = 0$, we can re-arrange the above equation to obtain:

$$V(a, d, t) = \frac{(1 - e^{-\sigma}) + (R_a - \psi)\,\gamma_{at} + \dot{\gamma_{at}} + \lambda\,(\gamma_{at} - \theta)}{\rho + \sigma} a + \frac{-\,(1 - e^{-\sigma}) - r\gamma_{at} - \dot{\gamma_{at}} - \lambda\gamma_{at})}{\rho + \sigma} d \tag{34}$$

Since λ is also an endogenous variable, we use equation (26) to show neither constant depends on current choices:

$$V(a,d,t) = \underbrace{\frac{(1-e^{-\sigma}) + (R_a-\psi)\,\gamma_{at} + \dot{\gamma_{at}} + \frac{(R_a-\psi-r)\gamma_{at}}{\theta}(\gamma_{at}-\theta)}{\rho+\sigma}}_{\gamma_{at}} a \tag{35}$$

$$+ \underbrace{\frac{-(1-e^{-\sigma}) - r\gamma_{at} - \dot{\gamma_{at}} - \frac{(R_a-\psi-r)\gamma_{at}}{\theta}\gamma_{at})}{\rho+\sigma}}_{\gamma_{dt}} d$$

Since we know $\gamma_{at} = -\gamma_{dt} = \gamma_t$, we can simplify:

$$V(a,d,t) = \gamma_t(a-d) = \gamma_t n \tag{36}$$

Where the constant multiplying net worth is the solution to the differential equation

$$\dot{\gamma_t} = \left(\rho+\sigma-r-\frac{(R_a-\psi-r)\gamma_t}{\theta}\right)\gamma_t - \left(1-e^{-\sigma}\right) \tag{37}$$

Note that when the constraint binds, and $V=\theta a$ and $V=\gamma_t n$ imply the following expression for bank leverage φ_t:

$$\varphi_t = \frac{a}{n} = \frac{\gamma_t}{\theta} \tag{38}$$

This implies the following differential equation for bank leverage when the constraint is binding:

$$\dot{\varphi_t} = (\rho+\sigma-r-(R_a-\psi-r)\,\varphi_t)\,\varphi_t - \frac{(1-e^{-\sigma})}{\theta} \tag{39}$$

In a stationary distribution with constant prices, γ_t, and φ_t, leverage is given by the quadratic implied by (21) when $\dot{\varphi_t}=0$:

$$\varphi = \frac{(\rho+\sigma-r) - \left((\rho+\sigma-r)^2 - \frac{4(R_a-\psi-r)\left(1-e^{-\sigma}\right)}{\theta}\right)^{\frac{1}{2}}}{2\,(R_a-\psi-r)} \tag{40}$$

In general, under relevant parameterizations, this implies leverage ratios in steady state are positively associated with credit spreads.

K.0.1 Steady State for the Banking Sector

The deposit rate and spread are targeted directly, and σ are calibrated, and the deposit rate r is derived from the household problem. So, we need to pick ψ and θ to target leverage φ and the spread $R_a - r$. Given this result, we find the w_b that is consistent with an aggregate stationary steady state. That is, we have no net worth growth in the aggregate: $\frac{\dot{N}}{N} = 0$. This implies:

$$w_b = 1 - \frac{e^{-\sigma}}{1-e^{-\sigma}}\left[\left(R_a - \psi - r\right)\Phi + r\right] \tag{41}$$

Noting that aggregate leverage is equal to bank leverage, set equal to the expression for bank leverage to obtain the steady state entrant wealth as a fraction of total bank net worth w_b as a function of parameters, the deposit rate (which in steady state is given by the household problem and $\rho = r$), and the spread:

$$w_b = 1 - \frac{e^{-\sigma}}{1-e^{-\sigma}}\left[\left(R_a - \psi - r\right)\frac{\sigma - \left(\sigma^2 - \frac{4(R_a-\psi-r)\left(1-e^{-\sigma}\right)}{\theta}\right)^{\frac{1}{2}}}{2\left(R_a - \psi - r\right)} + r\right] \tag{42}$$

L Algorithm

Given the above parameters and the target for the price-to-rent ratio, the bank's problem implies that in steady state we have:

$$\frac{R_h - \delta_H}{q_h} = r_m \implies \frac{1}{12} = r_m + \frac{\delta_h}{q_h} \implies q_h = \frac{\delta_h}{1/12 - r_m} \implies R_h = \frac{\delta_h}{1 - 12 r_m}$$

With q_h, we can now solve the entrepreneur's problem, which involves searching for ν_l such that $L = 0.67$. and

For the household, we have the following preferences:

$$U\left(C,1-L,H,H_R\right)=ln\left(C-\nu_l L\right)+\nu_H\left(\epsilon H^{1-\sigma_h}+\left(1-\epsilon\right)H_R^{1-\sigma_h}\right)^{\frac{1}{1-\sigma_h}}$$

From the Euler equation, in steady state we have:

$$r=\rho$$

Given calibration targets, we can then find:

$$M=q_h H_R*\frac{1}{3}$$

$$d_M=r_m M+q_h\delta_h H=\left(r_m\frac{1}{3}+\delta_h\right)q_h H$$

From the FOC for d_M and envelope for M, we have:

$$\left(r_m-\rho\right)\left(1+\phi\frac{d_M}{M}\right)=\frac{\phi}{2}\left(\frac{d_M}{M}\right)^2$$

Re-arranging, I can express the calibrated value for ϕ as a function of now known variables given targets:

$$\phi=\frac{r_m-\rho}{\frac{1}{2}\left(\frac{d_M}{M}\right)^2-\left(r_m-\rho\right)\frac{d_M}{M}}$$

From first order and envelope conditions, we have:

$$\left(\rho+\delta_h\right)\frac{q_h}{R_h}\left(1+\phi\frac{d_M}{M}\right)U_{H_R}=U_H$$

Using the assumed functional form and re-arranging, we have:

$$\left(\rho+\delta_h\right)\frac{q_h}{R_h}\left(1+\phi\frac{d_M}{M}\right)=\frac{\epsilon}{1-\epsilon}\left(\frac{H}{H_R}\right)^{-\sigma_h}$$

Re-arranging again, I can show that the calibrated value for ϵ is given by

$$\epsilon = \frac{(\rho+\delta_h)\left(1+\phi\frac{d_M}{M}\frac{R_h}{q_h}\left(\frac{H}{1-H}\right)^{\sigma_h}\right)}{1+(\rho+\delta_h)\left(1+\phi\frac{d_M}{M}\frac{R_h}{q_h}\left(\frac{H}{1-H}\right)^{\sigma_h}\right)}$$

Note that the right hand side contains all known values either from a calibration target, assumption, or previously derivation. Turning to the bank problem, since production sector liabilities L_B are known, M is known, and $q_h H_R$ is known, and furthermore we have the expression for bank leverage:

$$\Phi = \varphi = \frac{(\rho+\delta-r) - \left((\rho+\delta-r)^2 - \frac{4(r_m-\psi-r)\left(1-e^{-\delta}\right)}{\theta}\right)^{\frac{1}{2}}}{2\left(r_m-\psi-r\right)}$$

We then have bank leverage by definition:

$$\Phi = \frac{q_h H_R + M + L_B}{N}$$

We have $N = \frac{(q_h H_R + M + L_B)}{\Phi}$. Since the assets not funded by net worth come from deposits, then:

$$D = (\Phi-1)\,N = \frac{\Phi-1}{\Phi}\left(q_h H_R + M + L_B\right)$$

From the household budget constraint, then, we have:

$$C = rD + wL + \Pi - d_m - \phi\frac{d_m^2}{2M} - R_h H_R$$

Given the solution to the firm's problem is consistent with the target L:

$$\nu_H = \frac{R_h\,(1-H)^{\sigma_h}\left(\epsilon H^{1-\sigma_H} + (1-\epsilon)\,(1-H)^{1-\sigma_H}\right)^{\frac{-\sigma_h}{1-\sigma_h}}}{(1-\epsilon)\,(C-\nu_l L)}$$

L.1 Transition [FOR ONLINE PUBLICATION ONLY]

Our goal is to find the appropriate shock to generate a path of house prices by what was observed in the United States during the great recession and after. Thus we are targeting a house price path $\{q_h(t)\}$ that falls by 20 percent over 4 years, then rises back to its steady state level after 5 years.[42] The main results use a shock to the path $\{\epsilon(t)\}$ to match this house price path, so our goal is to find the appropriate path of this parameter to generate the observed house price movement. The algorithm in simple terms consists of the following steps:

1. Guess $\{r(t), r_m(t)\}_{t=0}^{T}$ for some large T where $r(T) = r$, and $r_m(T) = r_m$ meaning we have converged back to steady state.

2. Given our targeted path $\{q_h(t)\}_{t=0}^{T}$, we can solve for the rental rate path from the necessary conditions for equilibrium in the bank problem: $R_h(t) = r_m(t)q_h(t) + \delta_h - \frac{q_h(t+\Delta)-q_h(t)}{\Delta}$.

3. Solve transition path for firm, including aggregate production sector quantities: $\{B^+(t), B^-(t), L(t)\}$, where $B^+(t) = \int_i \mathbb{1}(b_i(t) \geq 0)\, b_i(t)di$, and $B^-(t) = \int_i \mathbb{1}(b_i(t) < 0)\, b_i(t)di$

   (a) Use backward induction to find path of value function, value function derivatives, and decision rules for producers in each period t.

   (b) Calculate mass of entrants in each period t.

   (c) Use Kolgomorov forward equation to solve for evolution of distribution.

Step 4: From FOC for HH problem, we have the time derivative approximation

[42] According to the FHFA, house prices fell by roughly 18%, whereas the S&P Case-Shiller indicates a larger decline of roughly 26%. It's debatable whether the appropriate recovery period is the time frame for house prices to reach pre crisis levels or trends. I use the former. The timing of the cycle in terms of peak/trough/recovery is roughly the same across the two house price measures.

of the Euler equation (suppressing arguments for choice variables):

$$(\rho - r(t))\, U_c(t) = \frac{U_c(t+\Delta) - U_c(t)}{\Delta}$$

Given $U_c(T)$, we can then solve backward:

$$U_c(t) = \frac{U_c(t+\Delta)}{(1 + \Delta\,(\rho - r(t)))}$$

Given the functional form, and the solution to the firm's problem which yields $L(t)$, we then have:

$$C(t) = \nu_l L(t) + (C(t+\Delta) - \nu L(t+\Delta))\,(1 + \Delta\,(\rho - r(t)))$$

So the path of consumption can be determined by backwards induction. Likewise, we can use the following FOC and envelope conditions to determine the ratio of mortgage payments to outstanding mortgage balances $\frac{d_m(t)}{M(t)}$. From the FOCs:

$$U_c(t) = V_d(t) \quad ; \quad V_d(t)\left(1 + \phi\left(\frac{d_m(t)}{M(t)}\right)\right) = -V_M(t)$$

The envelope condition for M:

$$\rho V_M(t) = V_d(t)\frac{\phi}{2}\left(\frac{d_m(t)}{M(t)}\right)^2 + r_m(t)V_M(t) + \frac{V_M(t+\Delta) - V_M(t)}{\Delta}$$

Together these imply:

$$(\Delta\,(r_m(t) - \rho) - 1)\left(1 + \phi\left(\frac{d_m(t)}{M(t)}\right)\right)U_c(t) = \Delta U_c(t)\frac{\phi}{2}\left(\frac{d_m(t)}{M(t)}\right)^2 - \left(1 + \phi\left(\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)\right)U_c(t+\Delta)$$

Applying the time derivative of Euler equation, dividing by $U_c(t)$, and re-arranging, we have the following quadratic:

$$\Delta\frac{\phi}{2}\left(\frac{d_m(t)}{M(t)}\right)^2+(1-\Delta\left(r_m(t)-\rho\right))\left(1+\phi\left(\frac{d_m(t)}{M(t)}\right)\right)-\left(1+\phi\left(\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)\right)(1+\Delta\left(\rho-r(t)\right))=0$$

$$\frac{d_m(t)}{M(t)}=\frac{-\phi\left(1-\Delta\left(\rho-r_m(t)\right)\right)}{\Delta\phi}+$$

$$\frac{\left(\phi^2\left(1-\Delta\left(\rho-r_m(t)\right)\right)^2-2\Delta\phi\left(\left(1-\Delta\left(\rho-r_m(t)\right)\right)-\left(1+\Delta\left(\rho-r(t)\right)\right)\left(1+\phi\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)\right)\right)^{\frac{1}{2}}}{\Delta\phi}$$

Where the positive root is used since deposits are non-negative.

Step 5: Given initial bank states $\{N(0), A(0), D_B(0)\}$ where $D_B(0)$ are bank deposits, solve for path of bank deposits and household deposits, taking the solution to production sector deposits and liabilities $\{D_P(t), L_P(t)\}$ from the aggregated solutions to the firms' problems, where $D_P(t)=\int \mathbb{1}\left(b(t)\geq 0\right)b(t)d\mu_t$ and $L_P(t)=wL(t)+\int \mathbb{1}\left(b(t)<0\right)b(t)d\mu_t$. From the bank problem, we know:

$$N(t+\Delta)=N(t)\left(1+\Delta\left(1-e^{-\sigma}\left(1-r_d(t)\right)\right)\right)+\Delta e^{-\sigma}\left(r_\ell\left(t\right)-r_d\left(t\right)\right)A(t)+\Delta W_B$$

Assuming the enforcement constraints bind, individual bank assets follow the law of motion $\dot{a}=\left(\rho+\delta\right)a-\left(1-e^{-\sigma}\right)\frac{n}{\theta}$, so aggregate assets evolve as follows:

$$A(t+\Delta)=A(t)+\Delta e^{-\sigma}\left(\left(\rho+\sigma\right)A(t)-\left(1-e^{-\sigma}\right)\frac{N(t)}{\theta}\right)-\Delta\left(1-e^{-\sigma}\right)A(t)+\Delta W_B\frac{A(t)}{N(t)}$$

Then, we can find the evolution of household deposits:

$$D(t)=D_B(t)-D_P(t)=A(t)-N(t)-D_P(t)$$

Step 6: Given a path of interest rates, decisions for $\{L(t), C(t), \frac{d_m(t)}{M(t)}\}$, a path of deposits $\{D(t)\}$, and initial conditions $\{D(0), M(0), H(0)\}$, we can solve for the evolution of assets and the rental housing taste parameters as follows. The envelope condition for housing gives:

$$\left(1+\Delta\left(\rho+\delta_h\right)\right)V_H(t)=\Delta U_H(t)+V_H(t+\Delta)$$

From the FOCs, we have:

$$V_H(t)=-q_h(t)V_M(t)=q_h(t)\left(1+\phi\frac{d_m(t)}{M(t)}\right)V_D(t)=q_h(t)\left(1+\phi\frac{d_m(t)}{M(t)}\right)U_c(t)$$

Plugging into the envelope condition, and using the intertemporal Euler equation, we have:

$$\left(1+\Delta\left(\rho+\delta_h\right)\right)q_h(t)\left(1+\phi\frac{d_m(t)}{M(t)}\right)U_c(t)=\Delta U_H(t)+q_h(t+\Delta)\left(1+\phi\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)\left(1+\Delta\left(\rho-r(t)\right)\right)U_c(t)$$

Dividing both sides by $U_c(t)$ and recognizing $\frac{U_{H_r}(t)}{R_h(t)}=U_c(t)$

$$\left(1+\Delta\left(\rho+\delta_h\right)\right)\left(1+\phi\frac{d_m(t)}{M(t)}\right)q_h(t)=\Delta R_h(t)\frac{U_H(t)}{U_{H_R}(t)}+q_h(t+\Delta)\left(1+\phi\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)\left(1+\Delta\left(\rho-r(t)\right)\right)$$

Plugging in the functional form for housing and re-arranging, we have:

$$\frac{\epsilon(t)}{1-\epsilon(t)}=\frac{\left[\left(1+\Delta\left(\rho+\delta_h\right)\right)\left(1+\phi\frac{d_m(t)}{M(t)}\right)q_h(t)-\left(1+\phi\frac{d_m(t+\Delta)}{M(t+\Delta}\right)\left(1+\Delta\left(\rho-r(t)\right)\right)q_H\left(t+\Delta\right)\right]\left(\frac{H(t)}{1-H(t)}\right)^{\sigma_h}}{\Delta R_h(t)}$$

Defining the left hand side as $\epsilon_{ratio}(t)$, we have:

$$\epsilon(t)=\frac{\epsilon_{ratio}(t)}{1+\epsilon_{ratio}(t)}$$

Re-arranging the evolution of mortgages, we have:

$$M(t+\Delta)=\left(1+\Delta\left(r_m(t)-\frac{d_m(t)}{M(t)}\right)\right)M(t)+q_h\left(t\right)\left(H_R(t)-H_R\left(t+\Delta\right)\right)$$

Define $NI(t) = r(t)D(t) + wL(t) + \pi(t)$, and plugging into the budget constraint:

$$H_R(t+\Delta) =$$

$$\frac{NI(t+\Delta) - C(t+\Delta) - \frac{B(t+2\Delta)-B(t+\Delta)}{\Delta} - \left(\frac{d_m(t+\Delta)}{M(t+\Delta)} + \frac{\phi}{2}\frac{d_m(t+\Delta)^2}{M(t+\Delta)^2}\right)\left(\left(1+\Delta\left(r_m(t) - \frac{d_m(t)}{M(t)}\right)\right)M(t) + q_h(t)H_R(t)\right)}{R_H(t+\Delta) - q_h(t)\frac{d_m(t+\Delta)}{M(t+\Delta)}\left(1+\frac{\phi}{2}\frac{d_m(t+\Delta)}{M(t+\Delta)}\right)}$$

This then gives $H(t+\Delta) = 1 - H_R(t+\Delta)$, and mortgages:

$$M(t+\Delta) = \left(1+\Delta\left(r_m(t) - \frac{d_m(t)}{M(t)}\right)\right)M(t) + q_h(t)\left(H(t+\Delta) - H(t)\right)$$

Finally, $\epsilon(t+\Delta)$ can be found as before. Repeating each step above, one can find a path of household assets $\{H(t), M(t), B(t)\}_{t=0}^{T}$ and parameter path $\{\epsilon(t)\}_{t=0}^{T}$ that is consistent with the bank problem and targeted path of house prices, given the interest rate guesses.

Step 7: Check asset market clearing conditions in each time period. Specifically, and asset markets clear $A(t) = M(t) + B(t) + wL(t) + \int \mathbb{1}\left(b(t) < 0\right) b(t) d\mu_t$. If asset markets clear, proceed to step 8. If not, and implied bank assets $A(t)$ are greater than combined household/production sector liabilities, then lower lending rates, if bank assets are less than implied liabilities, raise the lending rate in that time period. Then go back to step 2.

Step 8: Check that output markets clear:

$$C(t)+q_h\delta_h+\int_i \left(c(z,k,b,t) + i(z,k,b,t) + f(i(z,k,b,t),k)\right)d\mu_t+\left[\left(r_\ell(t) - \psi - r(t)\right)A(t) + r(t)N(t)\right] = \int y_i^\rho di$$

If markets clear, then we have a solution. If not, and output is greater than consumption, lower the deposit rate. If output is less than consumption, then raise the interest rate. Return to step 2.