

Collateral Damage: Housing, Entrepreneurship, and Job Creation^{*}

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Abstract

Entrepreneurial activity in the U.S. collapsed prior to and during the Great Recession. This collapse was significant in terms of both new firm formation and entrepreneurial employment, and it coincided with a historic decline in home values that preceded the onset of the broad recession by at least nine months. I construct a heterogeneous agent DSGE model with both housing and entrepreneurship. The model is characterized by financial frictions that affect both credit supply and credit demand. I consider the consequences of a “housing crisis” as compared to a “financial crisis.” The model produces a quantitatively meaningful, negative response of entrepreneurship to a housing crisis via a housing collateral channel; a financial crisis (which works through credit supply) has more nuanced effects, causing economic disruption that entices new low-productivity entrepreneurs into production. The broad financial crisis cannot account for the collapse in entrepreneurship, but recessions accompanied by a housing market collapse may be associated with significant reductions in entrepreneurial activity.

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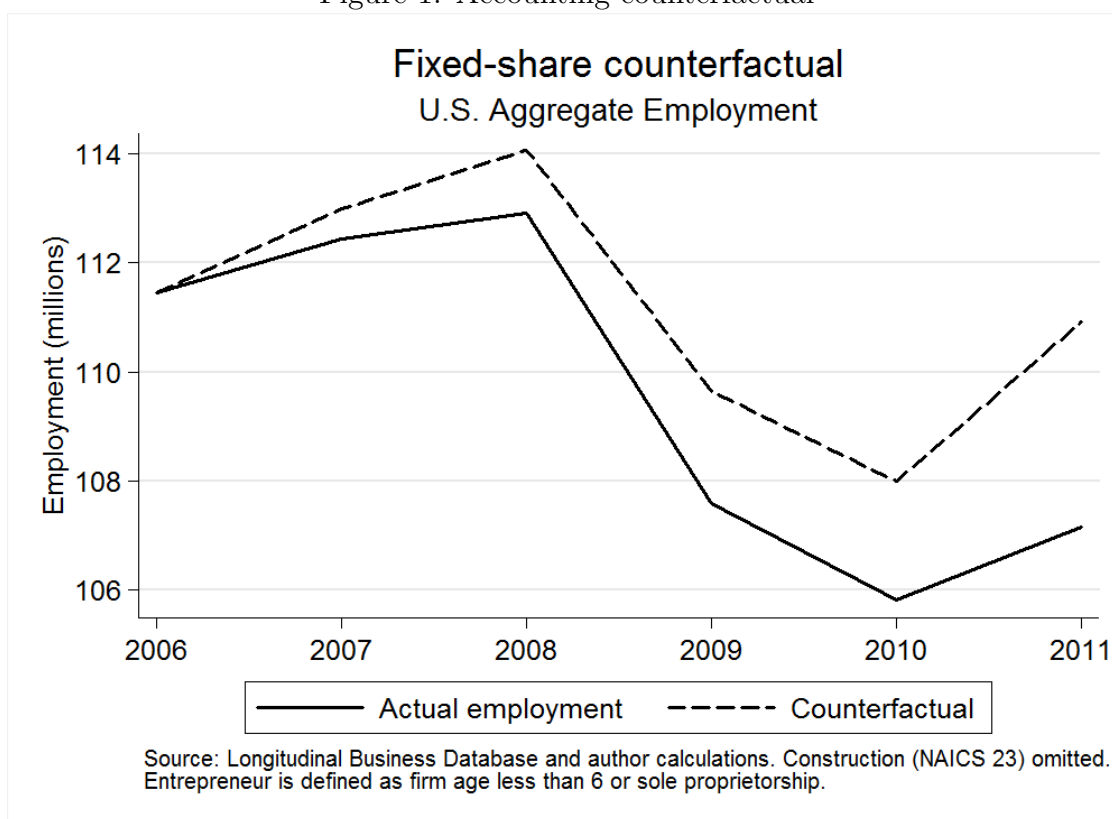
The Great Recession was preceded by a simultaneous decline in house prices and entrepreneurial activity, both of which were largely unprecedented in scale. Given the crucial job market role played by young firms, understanding the cause of the collapse in entrepreneurship is important. A growing empirical literature finds a close relationship between house prices and entrepreneurial activity and suggests the importance of housing collateral for entrepreneurial finance (Adelino, Schoar and Severino (2013), Fort et al. (2013), Mehrotra and Sergeyev (2014)). Other literature points to credit supply frictions as key drivers of the Great Recession (Adrian, Colla and Shin (2013)). What can account for the collapse in entrepreneurship? In particular, is the housing crisis to blame, or is the broader financial crisis that followed more likely to have caused the decline?

In this paper, I explore the collapse in entrepreneurship by constructing a model to contrast the effects of a housing crisis (which affects entrepreneurship through credit demand) with a financial crisis (which affects all firms through credit supply). The contribution of the model is to show that entrepreneurial activity declines in response to a housing crisis but not a financial crisis. Housing is an important source of collateral for entrepreneurs, while corporate firms are financed independently of the household assets of their owners. A broad financial crisis has roughly the same effect on all types of firms, so it is incapable of causing a disproportionate decline in entrepreneurship. More generally, the model's results suggest that recessions associated with a housing crisis are different in that they are naturally accompanied by depressed employment among entrepreneurs, with broad implications for aggregate job growth.

Understanding the cause of the collapse in entrepreneurship is important because young firms play a disproportionate role in aggregate job creation (Haltiwanger, Jarmin and Miranda (2013) and Haltiwanger (2012)). Fort et al. (2013) suggest that young firms account for about 22 percent of the decline of net job growth associated with the Great Recession. Consider the simple, rough accounting counterfactual reported in Figure 1. Define an “entrepreneur” as any firm that is less than six years old or is a sole proprietorship. In 2006,

the share of non-construction employment accounted for by entrepreneurs was 17 percent.¹ Suppose this *share* had stayed constant through 2011, while non-entrepreneurial employment remained as its actual level.² As Figure 1 shows, counterfactual employment has a higher peak in 2008, and the counterfactual trough in 2010 exceeds actual employment by about two million jobs. The observation for 2011 further shows a stronger recovery in the counterfactual. This is not a rigorous counterfactual, but it illustrates the large role played by entrepreneurs in the Great Recession.³

Figure 1: Accounting counterfactual



In principle, two key channels could link a housing crisis with the share of economic activity accounted for by entrepreneurs. The first is a housing demand mechanism, where

¹Data from the Census Bureau’s Longitudinal Business Database. Data are reported as of March of a given year. The construction industry is defined as two-digit NAICS code 23.

²Specifically, the counterfactual is constructed as follows: In 2006, non-construction entrepreneurs’ share of total non-construction employment was 17 percent. Then the non-entrepreneurial share of employment was 83 percent. Let e_t be non-entrepreneurial employment in time t , and let \hat{E}_t be counterfactual aggregate employment in time t . Then $\hat{E}_t = e_t/0.83$ for every t .

³A more detailed counterfactual is given by Sedlacek and Sterk (2014).

entrepreneurs in the construction sector and related sectors become distressed when demand for new housing falls.⁴ In the present study I abstract from this channel. The other possible channel operates through the balance sheets of entrepreneurs. Houses form a significant share of household assets, and entrepreneurial credit access depends heavily on the household assets of firm owners. In the decade prior to the housing crisis, households were increasingly able to “use their houses as an ATM,” including for business finance. In the model I describe below, entrepreneurial borrowing is constrained by the value of entrepreneurs’ personal asset holdings, including housing. The corporate sector faces no such constraints. This modeling approach is motivated by the notion that large, established firms can access credit through bond and commercial paper markets or large-scale bank borrowing, sources that do not depend on the asset holdings of firm owners. Conversely, entrepreneurs face constraints on borrowing based on their personal ability to supply collateral.

The effects of house prices on bank balance sheets and consumer spending have been studied extensively, and there is a large literature on the effect of financial constraints on job flows, the firm age (and size) distribution, and entrepreneurship. However, the relationship between housing and entrepreneurship has received less attention. I construct a heterogeneous agent DSGE model, based on the macroeconomic literature studying entrepreneurship, in which housing plays a collateral role for potential entrepreneurs. In the model, I define a “housing crisis” as a change in the collateral value of housing induced by either a taste shock that drives down the house price or a shock to the maximum loan-to-value ratio faced by households. I define a “financial crisis” as a shock to intermediation costs that manifests itself through a higher credit spread. Thus, the housing crisis operates through a credit demand channel by affecting household balance sheets, while the financial crisis operates through a credit supply channel and affects all firms (rather than only entrepreneurs). I compare model steady states and find that a housing crisis reduces entrepreneurship by an amount

⁴In 2006 entrepreneurial firms accounted for 30 percent of construction employment, compared with 17 percent of non-construction employment and 18 percent of employment generally (Longitudinal Business Database).

that is quantitatively comparable to the Great Recession. In contrast, a financial crisis has large effects on total output but does not reduce entrepreneurial activity disproportionately.

The model includes a corporate sector that is not subject to collateral constraints. As a result, shocks to the collateral constraint need not affect aggregate production, since corporate firms can increase output in response to reduced entrepreneurial activity. In this respect, the quantitative results I describe may be thought of as a lower bound on the effects of collateral shocks (and housing crises broadly) on entrepreneurial job creation. In the absence of a healthy non-entrepreneurial sector, aggregate demand effects could result in further reductions in entrepreneurial activity following a housing crisis.

The present study does not attempt to explain the path of house prices during the last decade, taking the large post-2005 decline as exogenous to aggregate entrepreneurial activity. I generate a housing crisis with a shock to housing preferences assuming constant, exogenous housing supply. I verify that my results are robust to an alternate experiment in which a house price drop is instead caused by an increase in the supply of houses.

Section 1 describes evidence and literature relevant to housing, entrepreneurship, and the model. Section 2 describes the model in detail. Section 3 describes the model calibration. Section 4 describes results from steady state experiments. Section 5 concludes.

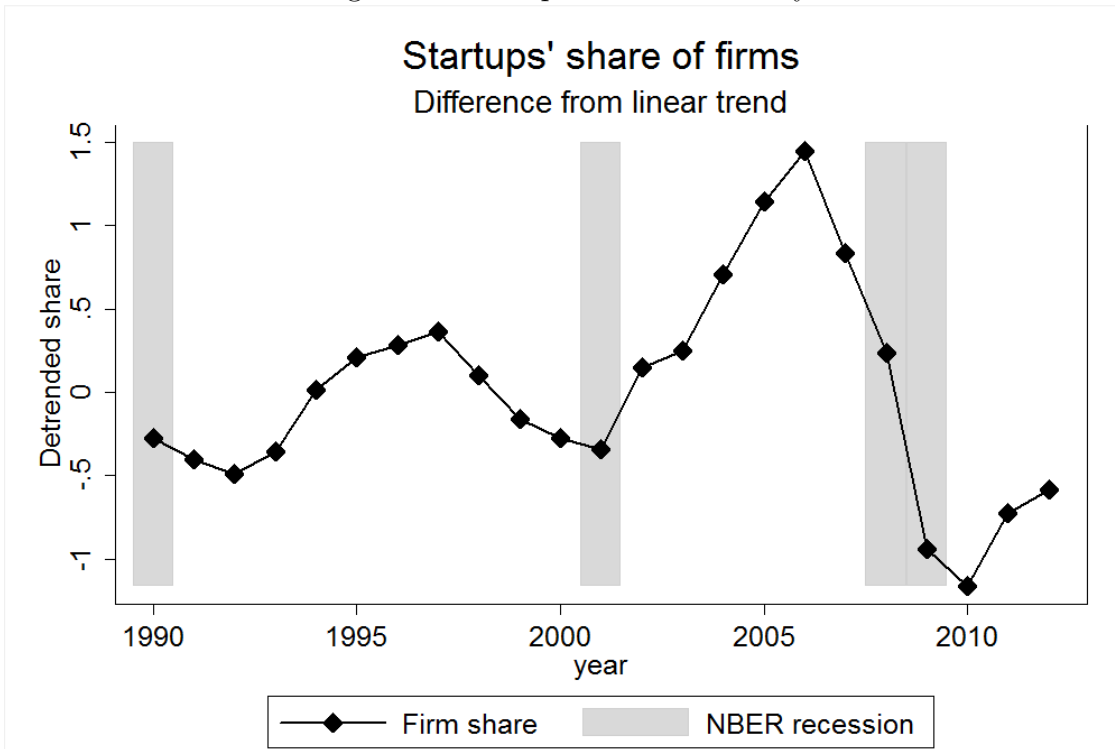
1 Evidence and previous literature

1.1 Data on housing and young firms

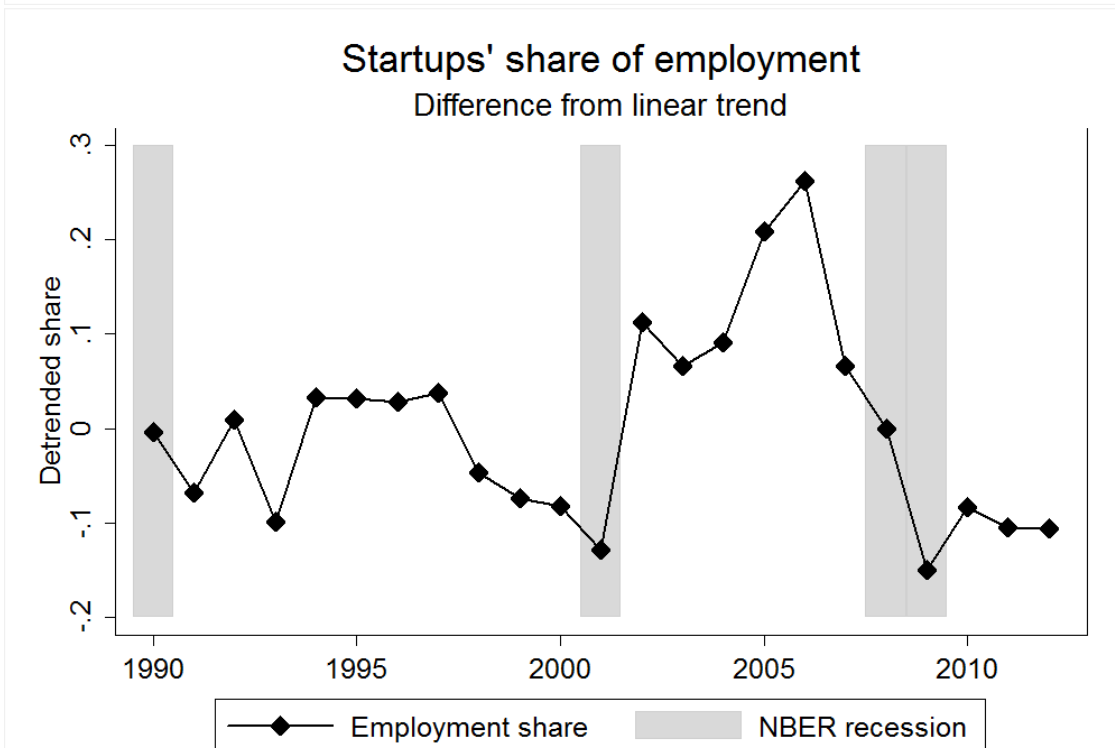
The Great Recession was preceded by a sharp decline in the number of new firms and the number of jobs created by startups and entrepreneurs (see Haltiwanger, Jarmin and Miranda (2011)); this fact holds even when the construction industry is ignored. Figure 2 shows data on startups as a share of firms and employment, detrended to abstract from long-term trends.⁵ While startup activity may be a leading indicator generally, the most

⁵Data on startups are from Business Dynamics Statistics, a publicly available dataset starting in the late 1970s that aggregates administrative data on the universe of private nonfarm establishments; establishments

Figure 2: Startups' share of activity



Source: Business Dynamics Statistics and NBER (annual data). Construction excluded.



Source: Business Dynamics Statistics and NBER (annual data). Construction excluded.

recent startup collapse was historically large.⁶

The timing of the decline in startup activity coincides broadly with the peak and deterioration of house prices and home equity. Figure 3 plots measures of startup activity (omitting construction) against the S&P/Case-Shiller national house price index and the value of owners' equity in real estate (from the Federal Reserve's Flow of Funds), with all series normalized by their 2000 levels.⁷ The top panel of Figure 3 shows quantities of startup firms and startup jobs, and the bottom panel shows startup firms and startup job creation as shares of overall firm totals.⁸ Both the house price series and the real estate equity series are reported quarterly; Figure 3 annualizes the data by simply using the first quarter of each year.⁹ Startup firm and jobs data are reported annually in March.

Readers should interpret the timing as follows: in the top panel of Figure 3, the number of startup firms and startup job creation peak in March 2006, and these peaks coincide with the peaks in first-quarter house prices and home equity. The bottom panel of Figure 3 shows that the share of aggregate job creation due to startups also peaks in March 2006.¹⁰ In short, both panels of the figure show that house prices and startup activity fell between March 2006 and March 2007, while the NBER defines the Great Recession as beginning in December 2007. Hence, *the declines in house prices and startup activity led the recession by between nine and twenty-one months.*

The timing indicates that demand-side factors or broad financial sector explanations for are observed in March of each year. Recession bars in the figure are also based on annual data, where the following years count as recessions: 1981-1982, 1990, 2001, and 2008-2009. According to the NBER, the most recent recession began in December 2007 and ended in July 2009.

⁶Many startups are small, and the decline in small firm job creation in the mid-2000s expansion has been documented before (see Moscarini and Postel-Vinay (2008), Moscarini and Postel-Vinay (2012)). These explanations fail to distinguish between young and small firms, however, and given the specific role of young firms in job creation, additional focus on young firms is warranted. For data on the secular decline in entrepreneurship see Haltiwanger, Jarmin and Miranda (2012) and Decker et al. (2014).

⁷Federal Housing Finance Agency (FHFA) home prices show similar timing.

⁸The job creation measure is actually the startup *component* of the overall job creation rate, where the job creation rate is constructed as in Davis, Haltiwanger and Schuh (1998).

⁹Note that the quarterly S&P/Case-Shiller house price index is actually a three-month trailing moving average (S&P (2014)).

¹⁰This measure is constructed using data reported in both March 2006 and March 2005; it is the number of jobs accounted for by startups as of March 2006 divided by the average of the number of economywide jobs reported in March 2006 and 2005.

Figure 3: Startup activity and house prices

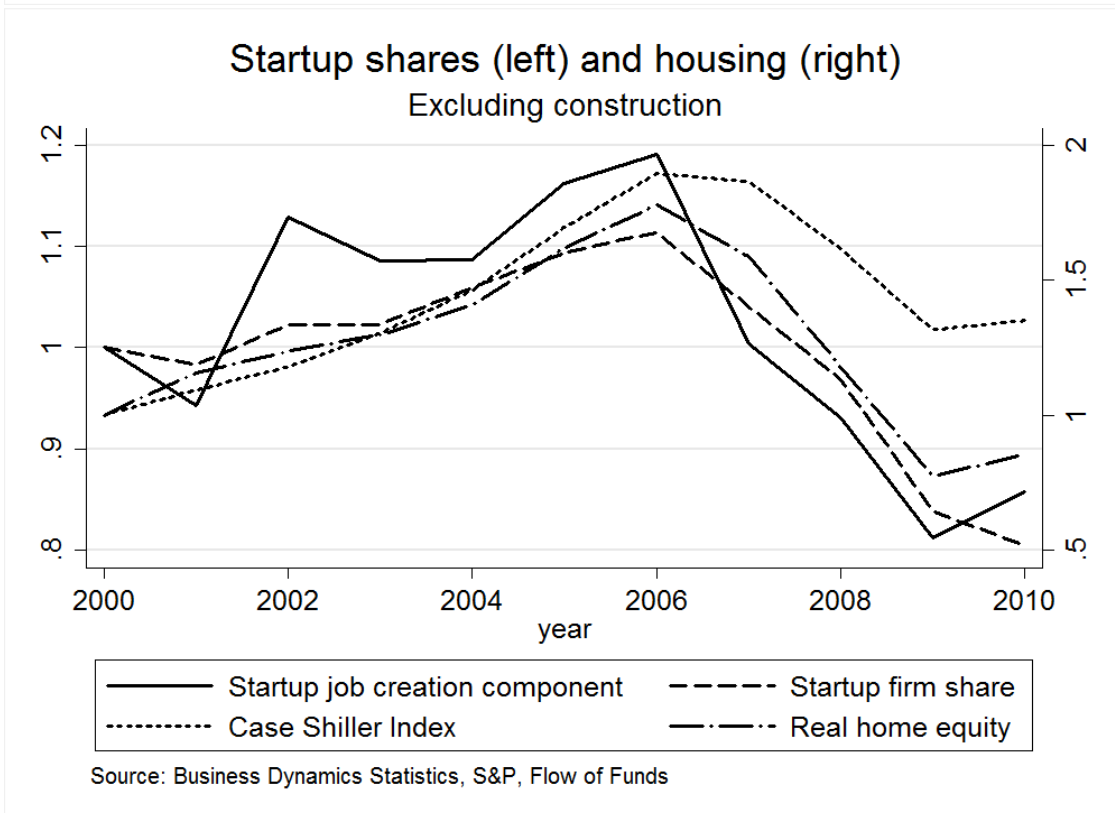
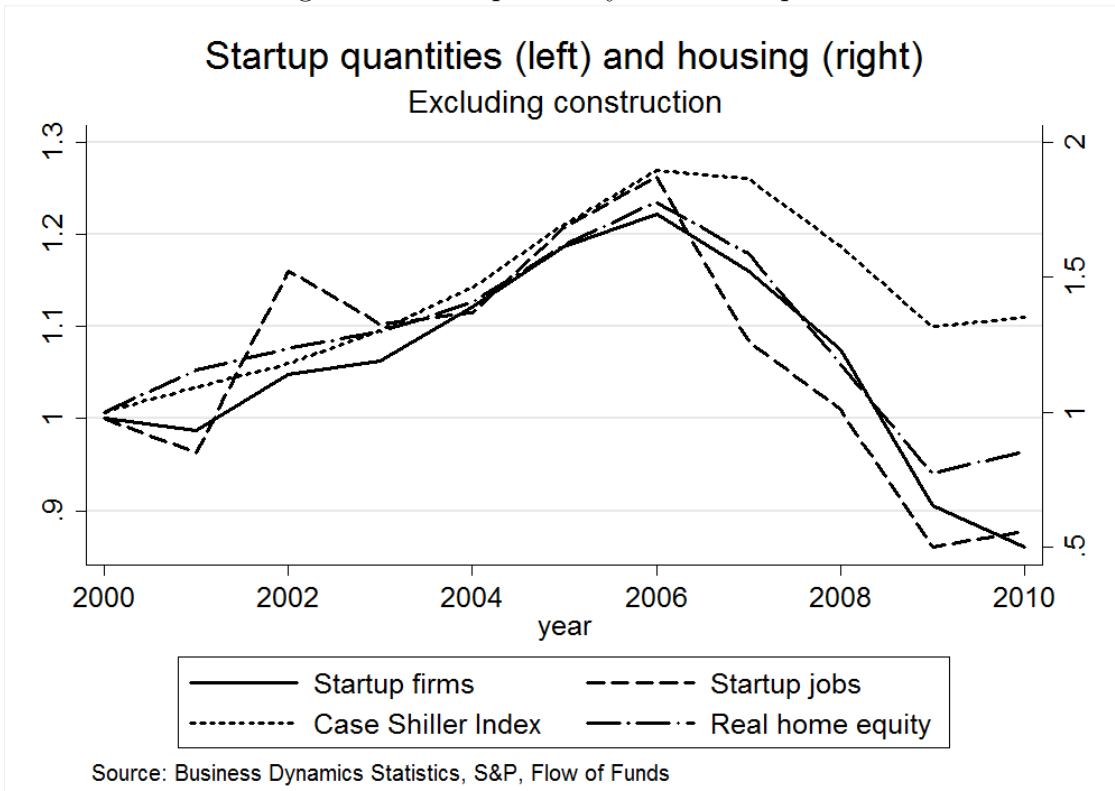
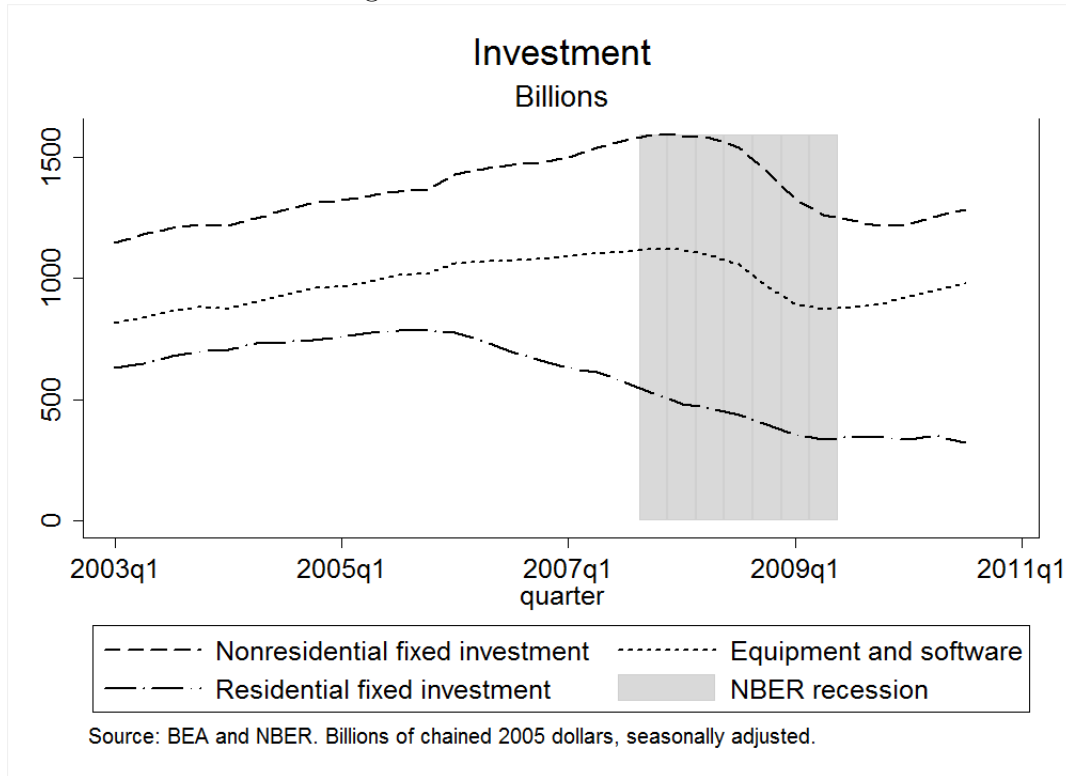


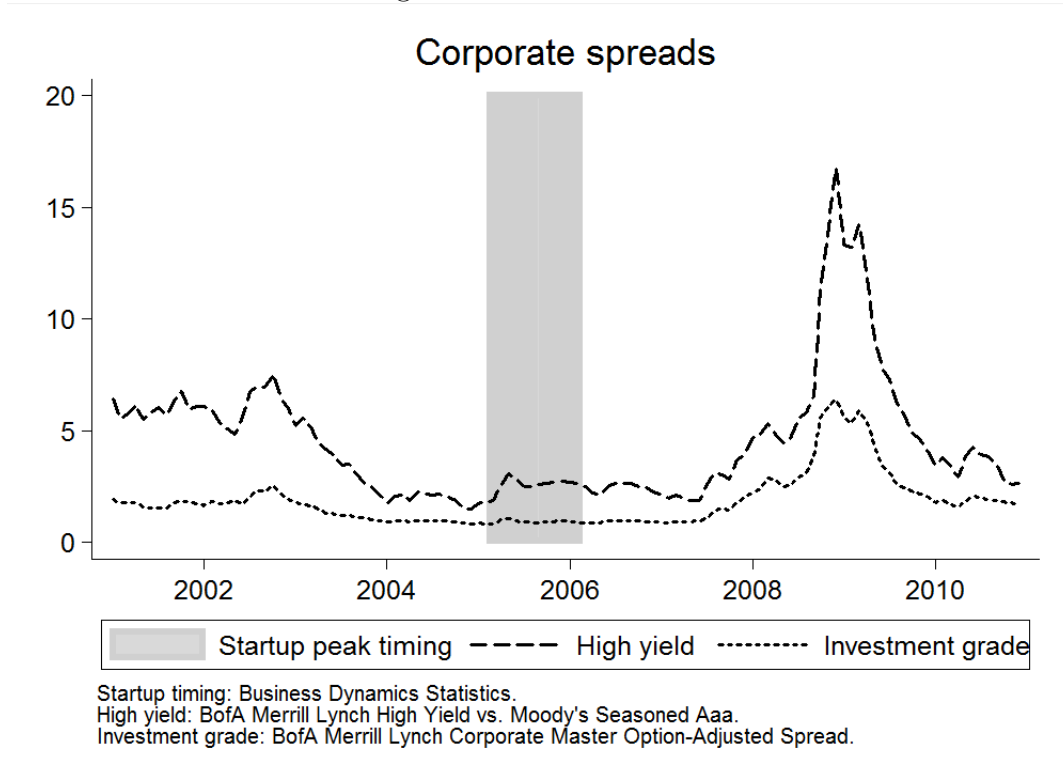
Figure 4: National investment



the link between startups and house prices may be inapplicable. For example, Figure 4 plots fixed nonresidential investment, investment in equipment and software, and fixed residential investment. It appears that the slowdown in startup activity which began between March 2006 and March 2007 was coincident with the decline in residential investment but prior to developments in other measures of investment. Figure 5 plots two measures of corporate spreads over time. Spreads did not begin rising until late 2007, and extreme highs were not reached until late 2008. The recession and broad financial sector stress started too late to explain the decline in entrepreneurial activity.

The empirical relationship between house prices and young firm activity is documented and explored more formally by Fort et al. (2013). The authors employ vector autoregressions to isolate the effect of temporally exogenous variation in house prices on young firm activity at the state level, concluding that “the collapse in housing prices play[ed] a critical role” in the dramatic decline in new firm formation and young firm job flows prior to and during

Figure 5: Financial stress



the Great Recession. More evidence is provided by Adelino, Schoar and Severino (2013). Using estimates of housing supply elasticities from Saiz (2010) as an instrument for house price changes at the metropolitan statistical area (MSA) level, Adelino et al. find that exogenous increases in house prices between 2002 and 2007 (where “exogenous” is defined in terms of the elasticity instrument) were associated with increased employment in small businesses relative to large businesses. This effect is particularly strong for businesses in industries that typically rely heavily on external financing, and the effect is strong even in tradeable industries, implying that the effect of house prices is not solely due to the impact of house prices on local consumption demand. Mehrotra and Sergeyev (2014) find similar MSA-level results for young firms.¹¹ The present study provides a structural explanation for

¹¹In the present study I focus on the relationship between house values and the ability of entrepreneurs to finance business activities; a related literature examines the relationship between house values and consumer spending. That housing matters for consumer decisions and aggregate fluctuations has been well documented (see, *e.g.*, Cooper (2013), Mian and Sufi (2011), Mian, Rao and Sufi (2013), Mian, Sufi and Trebbi (2014)). However, the consumption channel cannot explain the disproportionate decline in entrepreneurial activity. Moreover, Fort et al. (2013) note that, given the tendency of young firm finances to be linked to household

the empirical relationship between house prices and entrepreneurship.

1.2 Young and small business credit

Firm size has a large impact on credit access (Cole and Wolken (1995)). Small businesses borrow primarily from commercial banks rather than by assuming debt securities. Small firms also frequently use credit cards and other “nontraditional” finance sources (Mishkin (2008); *Frequently asked questions about small business finance* (2011)). Many young firms are small and may therefore be subject to such financial constraints. Adrian, Colla and Shin (2013) report that large firms were largely able to replace bank financing with bond financing in the wake of the financial crisis, but this is not an option available to most young and small firms.

Entrepreneurial credit often lies at the intersection of business and household lending (Cole and Wolken (1995)). The Federal Reserve Board conducts a quarterly survey of senior loan officers at approximately sixty domestic banks and some foreign banks operating domestically (all past surveys are available at *Senior Loan Officer Opinion Survey on Bank Lending Practices* (2014)). The 2007 surveys indicate a gradual but steady move toward tighter mortgage lending standards, although they have no direct questions about collateral. The January 2008 survey found that “between about 70 percent and 80 percent of domestic respondents expect the quality of their prime, nontraditional, and subprime residential mortgage loans, as well as of their revolving home equity loans, to deteriorate in 2008.” The April 2008 survey found that “all respondents pointed to declines in the value of the collateral significantly below the appraised value for the purposes of the HELOCs [home equity lines of credit] as reasons for tightening terms on those lines.” Subsequent surveys indicated ongoing tightening of HELOC standards. Overall, while the surveys do not provide direct evidence about housing collateral and business lending, they do indicate steadily stricter loan-to-value ratios and other standards starting in late 2006 as lenders began to notice that

finances, the Mian et al. results are consistent with a firm credit channel of house prices, with the link depending on firm age.

lending against housing was becoming riskier.¹²

The relationship between house prices and entrepreneurship has changed over the last two decades. Few small businesses reported reliance on mortgage credit in 1993 (Cole and Wolken (1995)), but this number increased during the 1990s (Bitler, Robb and Wolken (2001)). Growth in entrepreneurs' reliance on credit lines and bank loans during this period is also evident (Mach and Wolken (2006)), but the nature of the collateral backing these lines is difficult to determine in the data. By 2007, about one quarter of small business owners reported that they used home equity for business financing (Schweitzer and Shane (2010)). I take these changes in entrepreneurial finance as exogenous; that is, I do not investigate why home equity-related business borrowing grew in recent decades. My model is not intended to explain entrepreneurial activity prior to the wide availability of home equity-based borrowing, so I would not expect the relationship between house prices and startups to be strong in previous years. Regardless, my findings are likely to have broad implications for not only the Great Recession but also future periods of housing crisis or collateral crisis generally.

While it is difficult to investigate the role of housing collateral for startup credit directly, it is clear that (a) new (and small) firms are largely lacking in access to the types of credit facilities enjoyed by large firms, and (b) young and small firms rely heavily on external credit for operation (Robb and Robinson (2012)). Lacking any earnings history, new firms' access to credit may therefore depend heavily on collateral. These facts and implications are consistent with an important role for the decline of housing collateral value in the recent decline of entrepreneurial activity.

¹²In June 2012, I collected some limited anecdotal evidence by interviewing several community bankers. Each of them reported that collateral was the key criterion used to evaluate loan applications from prospective business creators. The bankers gave some weight to earnings history for older firms, but new firms lack such history. The dominant (and almost sole) sources of collateral for new firms were structures, with personal homes being very common. One banker reported that when house prices began declining, his bank virtually ceased making loans to new firms. All bankers reported having watched local housing conditions carefully during the house price decline, even in the context of non-construction business lending decisions. The bankers also reported sharp declines in loan-to-value ratios. One banker reported that, prior to 2006, small businesses often received loans in excess of 100 percent of collateral value, and all bankers reported that loan-to-value ratios were typically below 80 percent during and after the collapse in house prices.

1.3 Financial constraints and entrepreneurship

Several empirical studies have found evidence of financially constrained behavior among young firms or at least dependence of growth paths on initial assets. These include Angelini and Generale (2008) (using Italian data), Huynh and Petrunia (2010) (using Canadian data), Chaney, Sraer and Thesmar (2012), and Kleiner (2014). The conditional size distribution of financially constrained firms is different from the distribution of unconstrained firms, and the number of firms facing financial constraints is nontrivial. Firms with more initial assets grow faster, and real estate holdings in particular often serve as collateral and therefore can constrain growth and investment.

Theoretical research using heterogeneous agent models following Hopenhayn (1992) has found that including financial constraints can improve the models' ability to match U.S. data. Firm dynamics models find that financial frictions can account for the conditional size and age distributions of firms (Cooley and Quadrini (2001) D'Erasmus (2011)) and can cause persistent drops in productivity and output (Khan and Thomas (2013)). Entrepreneurship in particular has been studied with a variety of structural models (see Quadrini (2009)). Quadrini (2000) divides production between corporate and non-corporate sectors, allowing for the important separation between firm and household decisions for large, established firms while giving household characteristics strong relevance for startup activity. Models with entrepreneurship typically find significant consequences of borrowing constraints for households.¹³ Several recent studies focus on collateral and entrepreneurship in the Great Recession specifically (see Siemer (2014) and Mehrotra and Sergeyev (2014)).¹⁴

¹³Buera (2009) estimates the welfare costs of borrowing constraints to be about 6 percent of lifetime consumption. Cagetti and De Nardi (2006) argue that “the tightness of borrowing constraints and voluntary bequests are the main forces in determining the number of entrepreneurs, the size of their firms, the overall wealth concentration in the population, and the aggregate capital accumulation” (866).

¹⁴Hurst and Lusardi (2004) raised some controversy by finding no evidence of a strong relationship between household wealth and entrepreneurship among PSID households. However, Fairlie and Krashinsky (2012) argue that the Hurst and Lusardi (2004) results are mitigated when one distinguishes between entrepreneurial entry decisions driven by job loss and other reasons for entry. Fairlie (2013) finds that the impact of declining home equity on entrepreneurship was partially offset by increased job loss in the Great Recession, as weak labor markets drove some people into self employment.

A growing literature studies housing in general equilibrium models (see, *e.g.*, Iacoviello (2010), Iacoviello and Neri (2010), Iacoviello (2014), Guerrieri and Lorenzoni (2011), and Iacoviello and Pavan (2013)). Corradin and Popov (2013) construct a simple partial equilibrium model in which housing collateral matters for entrepreneurial decisions, but the model is highly stylized and largely abstracts from housing choice and differences between entrepreneurs and other firms.

To summarize, theoretical exercises and empirical evidence suggest that borrowing constraints are highly relevant for new businesses, and there is evidence that such constraints were among the key drivers of the real economy before and during the Great Recession. Moreover, home equity plays a significant economic role as the primary element of household balance sheets. The unique contribution of the present study is to investigate the pre-Great Recession collapse in entrepreneurial activity by comparing the consequences of a housing crisis (which acts as a credit demand friction) with a financial crisis (which acts as a credit supply friction) in a general equilibrium model that recognizes differences between entrepreneurs and larger, established firms.

2 Model

Consider a model of entrepreneurship based on Buera, Kaboski and Shin (2011) but augmented with housing (as in Iacoviello and Pavan (2013)) and a corporate production sector (as in Quadrini (2000)). Households choose whether to be workers or entrepreneurs. Housing can be owned or rented; owned housing can be used as collateral for consumer loans or capital rental. Housing supply is exogenous and constant. Households are distributed over a four-dimensional state space based on financial assets, owned housing, previous occupational status (so that new entrepreneurs may be different from incumbents), and entrepreneurial productivity (which is responsible for generating a wealth distribution). Output is produced by both entrepreneurs and a representative corporate firm.

A zero-profit financial sector borrows from households with positive savings to supply loanable funds, rental housing, and productive capital for entrepreneurs and the corporate firm. Loanable funds and rental capital are produced at an exogenously determined cost; in equilibrium this cost is manifested as a credit spread paid by borrowers and firms.

2.1 Environment

2.1.1 Households

There is a unit measure of infinitely lived households, each of which chooses either to be an entrepreneur or to supply one unit of labor. Their preferences are given by:

$$\mathbb{E} \left[\sum_{t=0}^{\infty} \beta^t u(c_t, m_t) \right]$$

where c_t denotes nondurable consumption, m_t denotes the flow of housing consumption, and $\beta \in (0, 1)$ is the discount factor. Hereafter I use recursive notation such that x indicates current-period flows and x' indicates intertemporal choices made in the current period. The period utility function has the following form:

$$u(c, m) = \frac{c^{1-\sigma_c}}{1-\sigma_c} + \varepsilon \frac{(\kappa m)^{1-\sigma_h}}{1-\sigma_h} \quad (1)$$

where κ governs the utility penalty for renting, with $\kappa < 1$ for renters and $\kappa = 1$ for homeowners (as in Iacoviello and Pavan (2013)). In the computational exercise described below, housing is discrete and can be owned and consumed in units of 500 square feet, and rented houses cannot exceed 2,500 square feet.¹⁵ The household's owned housing stock is

¹⁵The 2007 American Housing Survey reports that less than 9 percent of renting households live in houses larger than 2,500 square feet. In the model, the cap on rental unit size captures the notion that homeowners have greater latitude to choose large houses.

given by state variable h , where

$$h = \begin{cases} m & \text{if owner} \\ 0 & \text{if renter} \end{cases} \quad (2)$$

Whether a household owns or rents and, if owning, the amount of owned housing consumed are chosen in the period before the choice enters utility. This reflects time costs associated with home purchases and is consistent with the timing of the borrowing constraint described below. Note that this implies that the binary tenure decision is also made one period in advance, but the rental housing quantity decision is made in the same period in which it is consumed.

Housing is durable with depreciation rate δ_h . Nondurable consumption is the numeraire. Housing can be purchased at price q or rented from the financial intermediary at rate r^h (such that rented housing in quantity m costs $r^h q m$). Owned housing adjustment is costly as in Iacoviello and Pavan (2013); adjustment beyond replacement of depreciation ($h' \neq h$) results in cost $\psi q h$. This cost may be thought of as including realtor fees or renovation inconveniences, costs that are proportional to the market value of housing and housing materials. Note that a household changing from owning to renting pays this fee, as does an owning household that changes the size of its house. A household changing from renting to owning does not pay this cost as $h = 0$ in this case. Rental housing contracts last only one period and are opened and closed without friction, so renting households can change their housing consumption freely. This setup is an attempt to capture the notion that housing consumption is much more flexible for renters than for owners.

Households can be entrepreneurs ($e = 1$) or workers ($e = 0$); entrepreneurs have profits from decreasing returns to scale production while workers receive wage w . The household has access to asset a for saving or borrowing at rate r^a .

All household borrowing—both loanable funds and capital rental—is subject to a bor-

rowing constraint:

$$k \leq a + \phi qh \tag{3}$$

where k is capital demand for entrepreneurial production (with $k = 0$ for workers). Positive a indicates positive savings while negative a reflects borrowing; households may borrow up to the collateral value of their owned housing, given by ϕqh (so renters may not borrow at all and must have positive savings to engage in entrepreneurial production). When $k = 0$, the borrowing constraint may be thought of as a simple mortgage with loan-to-value ratio ϕ . The borrowing constraint is the model's mechanism for making entrepreneurial decisions and profits dependent on household balance sheets.

Capital is not owned by firms, so in effect entrepreneurial households face a requirement that working capital must be financed through borrowing. However, consider a special case in which $h = 0$, $a > 0$, and the rental rate on capital is not subject to a credit spread. This is equivalent to a model in which part (or all) of a household's financial wealth is held as physical capital, so that entrepreneurial capital is not rented but owned by the entrepreneurial household. Therefore, the working capital constraint setup differs from entrepreneurial ownership of capital when there is an intermediation cost (credit spread) or when the household owns housing. Housing is a versatile asset, since the ability to borrow against it to rent capital makes housing similar to owning productive capital.

The borrowing constraint given by (3) may be thought of as a reduced-form simplification of borrowing conditions motivated by agency problems. For example, Buera, Kaboski and Shin (2011) derive a capital rental constraint from an exogenous default recovery parameter faced by banks along with a no-default condition. In the event of default, banks can recover a fixed portion of entrepreneurial profits along with wealth deposited with the financial intermediary; the bank derives the borrowing constraint by choosing the maximum amount of loaned capital at which the household prefers repayment to default. The resulting level of

permissible capital rental is increasing in household wealth and entrepreneurial productivity. My simplified borrowing constraint has similar properties except that it discards the role of productivity in the constraint for tractability purposes. Further, I apply the loan-to-value parameter (which can be less than 1) to housing (and not liquid wealth) based on the notion that liquid wealth is relatively easy for the bank to seize and use while foreclosed housing is characterized by costs and risks that render it less valuable as loan security (from the bank’s perspective). In my specification, the borrowing constraint works like a technology allowing households to extract cash from their home (“use it as an ATM”).

2.1.2 Production

Entrepreneurs and the corporate sector produce the same final good which can be consumed, traded for housing, or (via the financial intermediary) used as productive capital. All firms rent capital from the financial intermediary at rate r^k and hire labor from a common labor market at wage w . Capital is rented, utilized, and returned to the financial intermediary within the period, so it is not an intertemporal decision for firms. Capital depreciates at rate δ_k .

The corporate sector consists of a representative firm with the following constant returns to scale technology:

$$Y_c = Z_c K_c^\xi N_c^{1-\xi} \tag{4}$$

where $\xi \in (0, 1)$. Z_c is (unchanging) corporate productivity, which will be normalized to 1, while K_c and N_c are corporate capital and labor demand, respectively. Corporate production does not involve fixed costs.

Entrepreneurs are households that choose to operate their decreasing returns to scale

production technology:

$$y_e = zk^\alpha n^\theta \tag{5}$$

where $\alpha \in (0, 1)$, $\theta \in (0, 1)$, and $\alpha + \theta < 1$. Capital demand is given by k and labor demand is given by n . All households receive an idiosyncratic entrepreneurial productivity draw z from a Pareto(x_m, η) distribution. Household productivity is persistent: each period, there is probability $(1 - \gamma)$ that the household receives a new z draw. Households that do not receive a new draw can produce with the same productivity as in the previous period. Households observe their entrepreneurial productivity before making their occupational decision. Startups (entrepreneurs that were workers in the previous period) pay an entry cost v , but incumbent entrepreneurs pay no fixed costs. The state variable s tracks entrepreneurial entry and is defined as follows:

$$s = \begin{cases} 0 & \text{if the household was an entrepreneur in the previous period} \\ 1 & \text{if the household was a worker in the previous period} \end{cases}$$

2.1.3 Financial sector

A representative financial intermediary borrows from savers at interest rate r and uses the savings to finance loans, capital, and rental housing. The financial intermediary owns all of the economy's capital and rental housing and therefore suffers depreciation losses. Additionally, conversion of savings into capital and loanable funds is subject to exogenous marginal intermediation cost τ . Technology for the production of capital, the allocation of loans, and the acquisition of rental housing is linear.

2.2 Recursive competitive equilibrium

Define $\mu(s, a, h, z)$ as the distribution of households over the state space. Then

$$\sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) dz dh da = 1$$

The distribution of households over the state space follows the law of motion

$$\mu'(s, a, h, z) = \Psi(\mu(s, a, h, z))$$

where Ψ depends on optimal policy rules a' and h' ; the law of motion for z , given by

$$z' = \begin{cases} z & \text{with probability } \gamma \\ z' \sim P(z) & \text{with probability } 1 - \gamma \end{cases}$$

and the law of motion for s , given by

$$s' = \begin{cases} 1 & \text{if } e(s, a, h, z) = 0 \\ 0 & \text{if } e(s, a, h, z) = 1 \end{cases}$$

Consider the following descriptions of model aggregates. A'_s is the total savings of households with positive financial assets, while A'_b is the total borrowing of households with negative financial assets (so $A'_b < 0$). H' and M_r are total housing demand among buyers and renters, respectively, and H_{adj} is the total owned housing stock among households that adjusted their housing holdings. C is total nondurable consumption. N_s is total labor supply (that is, the number of households that are workers), and N_e is total labor demand among entrepreneurs. K_e and Y_e are entrepreneurial capital demand and output, respectively. S_e is the total number of startups. These aggregates are constructed using state variables, policy functions, and the household distribution $\mu(s, a, h, z)$, and I define them in detail in

Appendix A.

Assume that $Y_c > 0$. The representative corporate firm maximizes profits with the following first-order conditions:

$$r^k = \xi Z_c \left(\frac{K_c}{N_c} \right)^{\xi-1} \quad (6)$$

$$w = (1 - \xi) Z_c \left(\frac{K_c}{N_c} \right)^{\xi} \quad (7)$$

This implies the following equilibrium relationship between the wage and the capital rental rate:

$$w = (1 - \xi) Z_c \left(\frac{r^k}{\xi Z_c} \right)^{\frac{\xi}{\xi-1}} \quad (8)$$

Since $\xi < 1$, this implies an inverse relationship between r^k and w .

Households maximize the value of lifetime utility, which is given by

$$v(s, a, h, z) = \max_{e \in \{0,1\}} \{v^{e=0}(s, a, h, z), v^{e=1}(s, a, h, z)\}$$

where $v^{e=0}(s, a, h, z)$ is the value of being a worker and $v^{e=1}(s, a, h, z)$ is the value of being an entrepreneur.

Households that choose to be workers ($e = 0$) solve the following problem:

$$v^{e=0}(s, a, h, z) = \max_{c \geq 0, a', h' \geq 0, m \geq 0} \{u(c, m) + \beta [\gamma v(1, a', h', z) + (1 - \gamma) \mathbb{E}_{z'} v(1, a', h', z')]\}$$

subject to

$$c + a' + q(h' - (1 - \delta_h)h) + \mathbb{I}_{rent} r^h qm + \mathbb{I}_{h' \neq h} \psi qh \leq w + (1 + r^a)a \quad (9)$$

$$0 \leq a + \phi qh$$

where \mathbb{I}_{rent} indicates housing tenure with

$$\mathbb{I}_{rent} = \begin{cases} 1 & \text{if } h = 0 \text{ (renter)} \\ 0 & \text{if } h = m \text{ (owner)} \end{cases} \quad (10)$$

and $\mathbb{I}_{h' \neq h}$ indicates housing adjustment with

$$\mathbb{I}_{h' \neq h} = \begin{cases} 1 & \text{if } h' \neq h \\ 0 & \text{if } h' = h \end{cases} \quad (11)$$

The s variable in the worker's value function $v^{e=0}(s, a, h, z)$ is trivial, since s does not affect the worker's choices. The definition of \mathbb{I}_{rent} given by (10) provides mutually exclusive possible values if the housing utility term satisfies the Inada condition, as in my specification (therefore $m > 0$).

For households that own housing ($h > 0$), the term m in the utility function is predetermined. Households that purchase enough housing to replace depreciation do not pay the adjustment cost ψqh ; equivalently, households are required to perform maintenance on their home to avoid the adjustment cost.

Households that choose to be entrepreneurs ($e = 1$) solve the following problem:

$$v^{e=1}(s, a, h, z) = \max_{c \geq 0, a' \geq 0, h' \geq 0, m \geq 0, k \geq 0, n \geq 0} \{u(c, m) + \beta [\gamma v(0, a', h', z) + (1 - \gamma) \mathbb{E}_{z'} v(0, a', h', z')]\}$$

subject to

$$c + a' + q(h' - (1 - \delta_h)h) + \mathbb{I}_{rent} r^h qm + \mathbb{I}_{h' \neq h} \psi qh \leq zk^\alpha n^\theta - r^k k - wn - sv + (1 + r^a)a \quad (12)$$

$$k \leq a + \phi qh$$

where \mathbb{I}_{rent} and $\mathbb{I}_{h' \neq h}$ are defined in (10) and (11), respectively, and v is the fixed entry cost paid by new entrepreneurs ($s = 1$). Again, m is predetermined for homeowners ($h > 0$). In general the household policy functions must be obtained numerically. However, the entrepreneurial capital and labor demand functions can be solved analytically using Kuhn-Tucker conditions. First, assume that the borrowing constraint does not bind. Then the entrepreneurial profit maximization problem is independent of both the household's state and the household's other decisions; the first-order conditions are:

$$k^u(z; r^k, w) = \left[\frac{r^k}{\alpha z} \left(\frac{\theta z}{w} \right)^{\frac{\theta}{\theta-1}} \right]^{\frac{\theta-1}{1-\alpha-\theta}} \quad (13)$$

$$n^u(z; r^k, w) = \left(\frac{w}{z\theta k^u(z; r, w)^\alpha} \right)^{\frac{1}{\theta-1}} \quad (14)$$

where k^u and n^u indicate unconstrained capital and labor demand, respectively. The unconstrained factor demand functions depend only on the wage w , the capital rental rate r^k , and productivity z . I have intentionally expressed labor demand as a function of capital demand, which simplifies the intuition in the constrained case. Now suppose that the borrowing constraint binds. Then labor demand still depends only on factor prices, productivity, and capital demand, but capital demand is given by the binding constraint. Hence, actual capital and labor demand functions are given by

$$k(z, a, h; r^k, w, q) = \begin{cases} \left[\frac{r^k}{\alpha z} \left(\frac{\theta z}{w} \right)^{\frac{\theta}{\theta-1}} \right]^{\frac{\theta-1}{1-\alpha-\theta}} & \text{if } k^u(z; r^k, q) \leq a + \phi q h \\ a + \phi q h & \text{otherwise} \end{cases} \quad (15)$$

$$n(z, a, h; r^k, w, q) = \left(\frac{w}{z\theta k(z, a, h; r^k, w, q)^\alpha} \right)^{\frac{1}{\theta-1}} \quad (16)$$

That is, capital demand equals its unconstrained level if that level is consistent with the borrowing constraint. Labor demand depends indirectly on the borrowing constraint because it is a function of capital demand. When the borrowing constraint binds, both factor demand

functions depend on household assets, the house price, and the loan-to-value ratio. The constraint on capital and labor demand implies a constraint on both entrepreneurial output and profits any time the entrepreneurs' optimal scale is larger than that allowed by the borrowing limit. This is the key mechanism for this model: a household with little financial and housing wealth can receive a large productivity draw but still be forced to operate at a scale that is well below the unconstrained optimal level, or may even choose to be a worker instead.

Taking the cost of funds r as given, the financial intermediary solves the following profit maximization problem:

$$\max_{K_c, K_e, A_b, M_r} r^k(K_c + K_e) - r^a A_b + r^h q M_r - \delta_k(K_c + K_e) - \delta_h q M_r - \tau(K_c + K_e - A_b) - r A_s$$

subject to

$$K_c + K_e - A_b + q M_r = A_s$$

that is, the financial intermediary lends out the total amount of household savings, dividing it between physical capital, loanable funds, and rental housing. Here I have defined r as the rate at which the financial intermediary borrows from saving households. The first-order conditions corresponding to the intermediary's choice variables are:

$$K_c, K_e : \quad r^k = r + \delta_k + \tau \quad (17)$$

$$A_b : \quad r^a = r + \tau \text{ (for borrowers)} \quad (18)$$

$$M_r : \quad r^h = r + \delta_h \quad (19)$$

Thus, the intermediation cost manifests itself as a credit spread with respect to the interest rate paid to savers. Agents that borrow from the bank must pay the basic interest rate along with extra payment to cover relevant depreciation and intermediation costs. Note that from

the households' perspective, r^a is defined as follows:

$$r_a = \begin{cases} r & \text{if } a \geq 0 \\ r + \tau & \text{if } a < 0 \end{cases}$$

It is simple to show that the financial intermediary, while owned by the households, has zero profits (see Appendix A).

In addition to the set of policy functions that solves the household's problem, equilibrium requires the following: The financial market clears:

$$K_e + K_c + qM_r = A_s + A_b \quad (20)$$

The labor market clears:

$$N_e + N_c = N_s \quad (21)$$

Define H_s as the exogenously set supply of housing. The housing market clears:

$$H + M_r = H_s \quad (22)$$

The aggregate resource constraint holds:

$$\begin{aligned} Y_e + Y_c - \psi q H_{adj} - \tau(K_c + K_e - A_b) - S_e v \\ = C + (K'_c - (1 - \delta_k)K_c) + (K'_e - (1 - \delta_k)K_e) + \delta_h q H_s \end{aligned} \quad (23)$$

where S_e is the number of startups.¹⁶ The resource constraint simply requires that consumption, investment, and housing depreciation costs (which are necessarily expressed in terms

¹⁶I provide the derivation of the resource constraint from household budget constraints in Appendix A.

of the numeraire good) be equal to total output after the costs of frictions—credit intermediation costs, housing adjustment costs, and firm entry costs. Housing investment does not appear in the resource constraint because the aggregate housing stock does not change over time. While it is uncommon for prices to appear in aggregate resource constraints, observe that the house price q enters here.

The house price affects the amount of real resources available in the economy in two ways. First, housing adjustment costs include the house price because, as with costs like realtor fees, such expenses are measured against the market value of the house. Second, housing depreciation costs may be thought of as the purchase of small amounts of housing units to perform maintenance. The purchases are necessarily subject to the house price, or the rate at which output goods can be exchanged for housing. Hence, a reduction in q makes agents wealthier in aggregate by reducing the costs of adjusting and maintaining houses, leaving more units of output available for consumption and investment. A model with an actual construction sector may not have this property.

The steady state is characterized by equilibrium prices and allocations with the distribution law of motion at a fixed point:

$$\mu = \Psi(\mu(s, a, h, z))$$

3 Calibration

I take several parameter values from existing literature; these are reported on Table 1. Many are standard values. I calibrate other parameters to match key moments from U.S. data. These are reported on Table 2.

Calibrated parameters are chosen such that the model resembles the U.S. economy around the year 2006, the peak of both house prices and startup activity in the U.S. The 2007 American Housing Survey (AHS) reports an average home size of 2,500 square feet (2007

Table 1: Literature-based parameterization

Parameter			Source
Discount factor	β	0.92	BKS (2011)
Relative risk aversion, nondurables	σ_c	1.5	BKS (2011)
Housing adjustment cost	ψ	0.05	IP (2013)
Entrepreneurial productivity persistence	γ	0.89	BKS (2011)
Rate of capital depreciation	δ_k	0.06	BKS (2011)
Rate of housing depreciation	δ_h	0.03	BEA
Entrepreneurial output capital parameter	α	0.299	BKS (2011)
Entrepreneurial output labor parameter	θ	0.491	BKS (2011)
Corporate output capital parameter	ξ	0.33	Quadrini (2000)

BKS: Buera, Kaboski, and Shin. IP: Iacoviello and Pavan.

BEA: Bureau of Economic Analysis tables; mean of residential structures

Table 2: Moment-based calibration

Parameter			Moment	Model	Data	Source
Housing supply	H_s	2.5	Average house size	2.5	2.5	AHS 2007
Housing taste	ε	0.52	Housing/GDP	1.8	1.8	FF 2006
RRA, housing	σ_h	1.56	Share of pop., >4,000 sq ft	0.09	0.05	AHS 2007
Rental utility parameter	κ	0.99	Renter share of population	0.33	0.32	AHS 2007
Entrep. TFP (scale)	x_m	1.28	Entrep. employment share	0.176	0.176	LBD 2006
Entrep. TFP (shape)	η	10.44	min/max entrep. size	0.06	0.04	LBD 2006
Entry cost	ν	0.68	Startup employment share	0.01	0.03	BDS 2006
Loan-to-value ratio	ϕ	0.92	2006 median LTV	0.92	0.92	Kalita (2011)
Intermediation cost	τ	0.009	Corporate spread	0.009	0.009	BofA/ML

FF: Flow of Funds. AHS: American Housing Survey. LBD: Longitudinal Business Database.

BDS: Business Dynamics Statistics.

BofA/ML: BofA/Merrill Lynch US Corporate Master Option-Adjusted Spread, 2006 average

is the closest year to 2006 for which the AHS exists). As mentioned above, I assume that housing exists in units of 500 square feet, so 2.5 housing units is 2,500 square feet. Since the economy has population normalized to one, an average house size of 2,500 square feet is equivalent to an aggregate housing supply of the same size.

Parameters governing housing demand are calibrated as follows. I calibrate ε so that the model produces a realistic value for the economy's owned housing stock (which directly relates to collateral value); I target the ratio of the value of housing to GDP, which was about 1.8 in the first quarter of 2006. The numerator is the total (nominal) market value of all real estate held by households and nonprofit organizations, reported by the Federal Reserve's Flow of Funds data; the denominator is nominal GDP. Since the Federal Funds measure does not include rental properties owned by businesses, in the model I define this ratio using owned housing only. I choose σ_h to match an aspect of the housing distribution, in particular the proportion of households living in houses larger than 4,000 square feet (rented or owned). An unrealistically large share of households living in large houses would result in too much collateral in the economy. The quantity is given by the 2007 AHS, which reports house size data in 500 square foot increments (as in the model). I calibrate the utility penalty for renting, given by κ , so that the proportion of households that rent approximately matches the U.S. rentership rate, which the AHS reports as about 32 percent in 2007. In general, the model matches the targeted housing distribution moments well.

The parameters of the Pareto(x_m, η) distribution for z are chosen to match the firm size distribution. While there is no objective definition of "entrepreneur" in the data, the model is motivated by credit constraints that are faced by young firms and other firms that have close ties to their owners' personal finances. As such, in the data I define a firm as an entrepreneur if it is less than six years old or is legally organized as a sole proprietorship. The scale parameter x_m is chosen to match the share of employment accounted for by entrepreneurs, which was 17.6 percent in 2006 according to the Longitudinal Business Database (LBD). Since the driver of heterogeneity in the model is z , the shape parameter η is used to

ensure a wide distribution of firms. The relevant model moment is the ratio of the smallest to the largest entrepreneur in terms of employment. To avoid extreme outliers, the corresponding data moment is the ratio of the employment of the 5th percentile entrepreneur to the 95th percentile entrepreneur from the 2006 LBD. The model matches the firm distribution reasonably well.

To target the share of employment accounted for by startups I use the entry cost v . In the model, startups are entrepreneurs that were workers in the previous period. In the data, startups are firms in their first year of existence. I obtain this moment from the 2006 Business Dynamics Statistics (BDS). The model produces too few startups as a share of employment, so in the following analysis I focus on entrepreneurs generally rather than startups specifically.

The remaining parameters are the loan-to-value ratio ϕ and the intermediation cost τ . The baseline value for the maximum loan-to-value ratio ϕ is based on data from Kalita (2011), which reports median loan-to-value ratios on new mortgages. The baseline value for the intermediation cost τ , which determines the exogenous credit spread, is based on the average of the Bank of America Merrill Lynch US Corporate Master Option-Adjusted Spread for the year 2006. In what follows, my policy experiments consist of varying τ , ϕ , and the housing taste parameter ε .

The solution method is described in Appendix B.

4 Results

4.1 Main experiments

I use the model described above to conduct four main experiments which are described concisely in Table 3 (the “Baseline” scenario is the model as calibrated to 2006-2007 data above). The purpose of these exercises is to compare the effects of a housing crisis and a financial crisis on entrepreneurial activity. I consider two different “housing crisis” scenarios.

In the first, I reduce housing tastes to induce a lower equilibrium house price. In particular, I change the housing taste ε from 0.517 (the baseline value calibrated above) to 0.362. This is chosen to produce a housing-to-GDP ratio of 1.2, corresponding to Flow of Funds data for the first quarter of 2011 (all other parameters are left as in Tables 1 and 2). This scenario is called “Taste” in the tables to follow. In the second housing crisis scenario, the loan-to-value ratio is changed from 0.92 (the baseline value corresponding to 2006) to 0.78, which corresponds with 2011 data from Kalita (2011) (again, all other parameters are left as in Tables 1 and 2). The loan-to-value ratio affects the household borrowing constraint in the same way as the house price, determining the collateral value of owned housing. This scenario is called “LTV” in the tables to follow. Each housing crisis scenario is designed to reduce the collateral value of housing.

The “financial crisis” scenario consists of an exogenous increase of the credit spread, reflecting increased frictions to credit supply. In reality credit spreads are endogenous, but in the model experiments I abstract from that endogeneity to focus on the specific channel leading from financial market turmoil to business activity. In the financial crisis scenario, I change the credit spread τ from 0.009 (the baseline value corresponding to 2006) to 0.037. The latter value is the average level of the Bank of America US Corporate Master Option-Adjusted Spread for the year 2009, the highest annual average of the Great Recession period. This value is chosen to capture the height of financial turmoil. This scenario is called “Spread” in the tables to follow.

In a fourth experiment, I conduct all experiments above simultaneously, creating a housing crisis and a financial crisis.

Table 4 describes key model outcomes for the baseline scenario and the four experiments described above. The baseline scenario produces a reasonable approximation to the U.S. economy around 2006 along dimensions that were not calibration targets. In the model, the homeownership rate is 83 percent for entrepreneurs and 66 percent for workers; in the 2007 Survey of Consumer Finances, the homeownership rates for entrepreneurs and workers are

Table 3: Steady state scenarios

	Taste	LTV Ratio	Spread
	ε	ϕ	τ
“Baseline”	0.517	0.92	0.009
“Taste”	0.362	0.92	0.009
“LTV”	0.517	0.78	0.009
“Spread”	0.517	0.92	0.037
“All”	0.362	0.78	0.037

Table 4: Steady state results

	Baseline	Taste	LTV	Spread	All
q	1.40	0.96	1.35	1.20	0.85
r	8.10	8.10	8.11	8.00	8.01
w	0.99	0.99	0.99	0.91	0.91
Entrepreneurial output	0.34	0.28	0.32	0.35	0.29
Total output	1.49	1.48	1.48	1.37	1.37
Entrepreneurial employment	0.17	0.14	0.16	0.19	0.16
Entrep. share of employment	0.176	0.147	0.168	0.201	0.163
Startup employment	0.013	0.010	0.012	0.014	0.011
Startup share of employment	0.013	0.011	0.013	0.015	0.011
Entrep. ownership rate	0.83	0.85	0.60	0.82	0.61
Worker ownership rate	0.66	0.63	0.57	0.66	0.59
Aggregate savings	3.99	3.79	4.21	3.21	3.08
Savings/GDP ratio	2.68	2.56	2.84	2.34	2.25
Housing/GDP ratio	1.78	1.19	1.52	1.65	1.06
Constrained entrepreneurs	0.845	0.852	0.852	0.797	0.801
Renters	0.33	0.36	0.43	0.33	0.41

82 percent and 67 percent, respectively. The model produces a ratio of savings to GDP of 2.68; the Flow of Funds reports a ratio of 2.83 in the first quarter of 2006.¹⁷

I now turn to discussion of experimental scenarios. Observe that the reduction in the taste for housing causes a decline of the steady state house price from 1.40 to 0.96, about 31 percent. By comparison, the S&P/Case-Shiller U.S. National Home Price Index shows a 32 percent decline across the calibration period (from the first quarter of 2006 to the first quarter of 2011).

¹⁷The numerator for this ratio in the Flow of Funds data is total financial assets held by households minus the value of corporate equities held by households. I subtract corporate equities because these are not included in the savings asset in the model. Model households do own corporate equities in the form of the zero-profit corporate firm, but I make no attempt to value it for this ratio.

The reduction in the taste for housing and the accompanying drop in the house price is associated with lower entrepreneurship, as hypothesized. Table 5 compares entrepreneurs’ and startups’ share of employment in the model with U.S. data from the LBD. The Model and Data columns corresponding with the initial 2006 state are calibrated to match each other, but other columns report model and data shares that are not necessarily equal by construction. Entrepreneurs’ share of employment falls from 17.6 percent to 14.7 percent in the model and to 14.1 percent in the data; that is, this experiment can account for 83 percent of the decline in entrepreneurs’ share. The experiment also produces a 15.4 percent drop in startups’ share of employment, compared with a 24.1 percent drop in the data.

Table 5: Model results compared to data

	Initial (2006)		Terminal (2011)		Change (%)	
	Model	Data	Model	Data	Model	Data
Entrep. share	0.176	0.176	0.147	0.141	-16.4	-19.9
Startup share	0.013	0.029	0.011	0.022	-15.4	-24.1

Entrepreneur data from LBD; startup data from BDS.

Changes in employment levels are also empirically plausible. From 2006 to 2011 the level of entrepreneurial employment in the LBD fell from about 21 million to about 16 million, a 24 percent drop. In the model experiment the level of entrepreneurial employment falls from 0.167 to 0.140, a 16 percent drop. From 2006 to 2011 the level of startup employment in the BDS fell from about 560,000 to about 400,000, a 29 percent drop. In the model experiment the level of startup employment falls from 0.013 to 0.010, a 23 percent drop. Generally these results are not surprising; the number of entrepreneurs who are at the borrowing constraint (“Constrained entrepreneurs”) rises by an amount equal to the rise generated by the experiment based on the loan-to-value ratio reduction. Moreover, the change in the number of constrained entrepreneurs does not tell the whole story, since entrepreneurs who would be constrained even with the higher house price now face a tighter constraint, moving them further from optimal productive scale.

The taste shock experiment has little effect on the interest rate, the wage, and output.

While entrepreneurial output falls, corporate output rises to compensate. There is no standard aggregate demand shock in the model; and since the corporate sector produces the same good as entrepreneurs total production need not fall. In that sense the results for entrepreneurial employment can be thought of as lower bounds, since they occur within a generally healthy economy. In the absence of a healthy corporate sector to provide compensatory labor demand, it is likely that the aggregate labor market would suffer from the drop in entrepreneurship. The experiment does result in an increase in rentership from 33 percent to 36 percent; the American Housing Survey reports an increase in the rentership rate from 32 percent in 2006 to 39 percent in 2011.

The other housing crisis experiment—a reduction in the loan-to-value ratio—has similar effects as the taste shock. Again, the interest rate, the wage, and output are roughly unchanged, so the experiment occurs within a healthy economy. Entrepreneurial and startup activity fall, albeit not as much as in the taste experiment. Note that the loan-to-value ratio enters the collateral constraint in the same way as the house price, but the decline in the multiplier on housing is different in the two experiments. Recall that the collateral constraint is given by

$$k \leq a + \phi qh$$

Table 6 reports the value of $q\phi$ for the five scenarios. The LTV scenario generates a larger collateral value of housing than the Taste scenario. As such, it is unsurprising that the LTV experiment does not reduce entrepreneurship as much as the Taste experiment. However, the number of constrained entrepreneurs is the same in the two experiments, suggesting that the differential effect is driven by the intensive margin, that is, the degree to which entrepreneurs are kept from operating at optimal scale.

As in the Taste experiment, rentership goes up in the LTV experiment—though the low loan-to-value ratio drives the rentership rate much higher than in the Taste scenario. This

is not entirely surprising—the value of owned housing as collateral is lower, while the house price is higher than in the taste scenario so that owned housing adjustment is still expensive. Combined, these factors make renting more attractive. However, the quantitative increase in rentership is counterfactually large, with rentership rising from 33 percent to 43 percent (as compared with 39 percent in the 2011 data). The ratio of household savings to GDP also rises in this scenario, from 2.68 to 2.84 (about 6 percent). This compares with a rise from 2.83 to 2.96 (about 5 percent) in Flow of Funds data from 2006 to 2011. The tightening of the collateral constraint boosts the precautionary saving motive, but this is apparently offset by the the role of the housing taste parameter in the household’s Euler equations.

Table 6: Collateral value of housing

	Baseline	Taste	LTV	Spread	All
ϕq	1.28	0.88	1.05	1.10	0.66

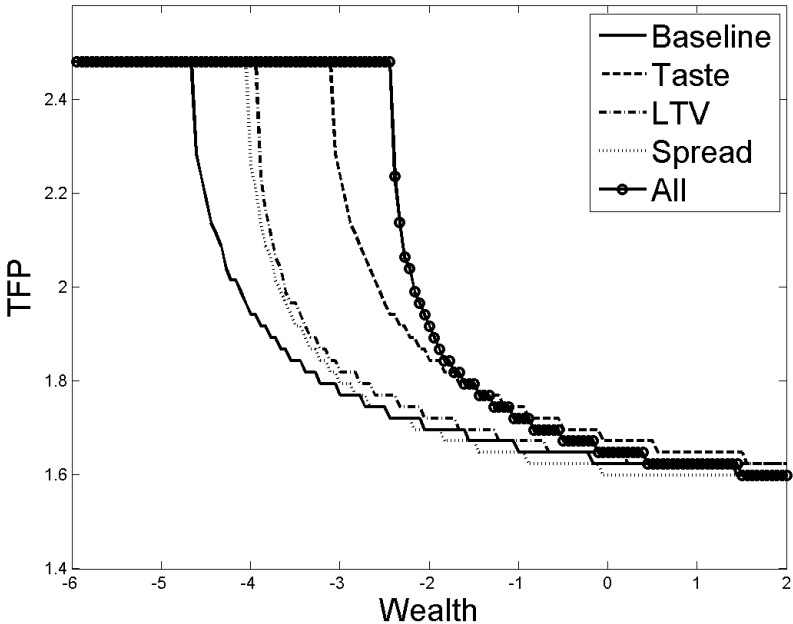
Qualitatively, both housing crisis experiments can produce a significant reduction in entrepreneurial activity, with the taste shock (and accompanying large drop in the house price) explaining a larger share of the empirical decline in entrepreneurship. This is not surprising since, as shown in Table 6, the collateral value of housing falls more in the Taste scenario than in the LTV scenario.

The financial crisis experiment produces results which differ starkly from both housing crisis scenarios. Recall that both entrepreneurs and the corporate sector are subject to the exogenous spread. An increase in the spread results in a 9 percent decline in output. The interest rate and wages both fall, along with household savings. Thus, a financial crisis results in broad economic stress.

All measures of entrepreneurial activity show significant increases under the high-spread scenario. To understand this, recall from the model that the entrepreneurial decision is heavily dependent on factor prices. The effective interest rate (including the spread) is the cost of capital rental, while the wage acts both as the cost of hired labor and the opportunity cost of being an entrepreneur. So both corporate and entrepreneurial profits depend on factor

prices, but only entrepreneurship is associated with the wage-as-opportunity-cost channel. The high-spread scenario is associated with a labor market that is less friendly to workers, which results in lower wages in this model, making entrepreneurship more attractive. Figure 6 illustrates this concept by showing the minimum productivity draw that is necessary to nudge a household into choosing entrepreneurship, plotted against household savings.¹⁸ The entrepreneurs at the bottom of the productivity distribution have small optimal scale, which may explain why the share of entrepreneurs that are credit constrained falls.

Figure 6: Productivity thresholds for entrepreneurship



The high-spread scenario illustrates a central claim of this study: supply-side financial frictions that affect all firms cannot explain the relative decline of entrepreneurial activity that occurred in the U.S. economy prior to and during the Great Recession. A financial crisis can have devastating effects on the economy generally, reducing output and wages, but it does not uniquely harm entrepreneurs and can even boost entrepreneurship by creating

¹⁸While the “marginal” entrepreneurs induced into production necessarily have low productivity, the model likely overstates their productivity relative to reality. These are likely to be “entrepreneurs of necessity,” whose labor market prospects are extremely grim. As such, the model likely overstates the amount of job creation that results from such entrepreneurs.

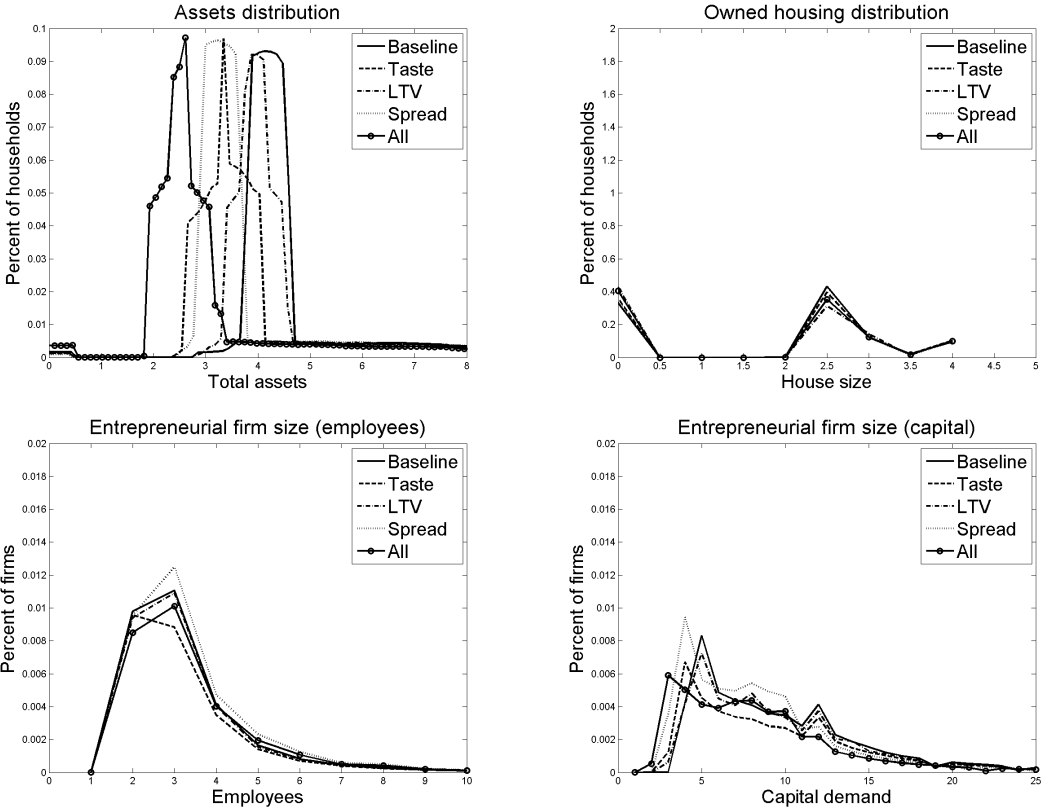
opportunistic entrepreneurs who want to escape an unhealthy labor market (these would include “entrepreneurs of necessity,” though the model does not include unemployment). The key to explaining a decline in entrepreneurial activity lies in the close relationship between household and business finances for entrepreneurs, which makes entrepreneurial activity heavily dependent on the value of household assets. Hence, a housing crisis can reduce entrepreneurship, but a general financial crisis cannot. In the next section I relax the assumption that corporate and entrepreneurial firms face the same credit spread.

Since the Great Recession involved a decline in both housing prices and the loan-to-value ratio as well as a heightened credit spread, the final experimental scenario performs all previous experiments simultaneously. Unsurprisingly, the results of this experiment resemble a compromise between the housing crisis and the financial crisis experiments. Output falls dramatically, depressing wages as in the high-spread scenario, but the wage-as-opportunity-cost mechanism is offset by tighter borrowing constraints on entrepreneurs which affect the extensive margin as well as firm scale. Hence, entrepreneurial activity falls relative to the baseline scenario, but it does not fall as much as in the housing crisis experiments. Compared with the baseline scenario, the “All” scenario sees the levels of entrepreneurial employment and startup employment fall by 6 percent and 15 percent, respectively, compared with 24 percent and 29 percent in the data. As a share of total employment, entrepreneurship falls by 11 percent and startups fall by 15 percent in the model, compared with 20 percent and 24 percent in the data. The “All” scenario explains a significant share of the decline in entrepreneurship observed during the Great Recession episode, though less than the housing crisis scenarios. Regardless, the experiment further confirms the importance of the housing collateral channel. An investigation of the consequences of housing and financial crises for unemployment is a useful question for future research.

Figure 7 plots distributions of several variables for each steady state scenario. Observe in all scenarios that the idiosyncratic productivity shock is sufficient to generate a wide distribution of households over asset holdings (which include savings and housing). Moreover,

the various experiments shift the high-density part of this distribution significantly. The economic costs of high credit spreads are illustrated in the downward shift of the household wealth distribution (shown in the top left panel of Figure 7). The role of the collateral constraint is illustrated by the effect it has on the entrepreneurial firm size distribution, which is illustrated in the bottom two panels of Figure 7. While Figure 6 illustrates the extensive margin effect of each experiment on entrepreneurship, the firm size charts show the intensive margin effect. Tighter credit for entrepreneurs means fewer, smaller entrepreneurs, with significant implications for aggregate entrepreneurial activity.

Figure 7: Distribution outcomes



To evaluate the quantitative implications of the housing crisis experiments, consider a set of counterfactuals (similar to the counterfactual shown in Figure 1) based on the “Taste” and “LTV” scenarios. Suppose that the *level* of non-entrepreneurial employment remained as in the U.S. data for 2006-2011 while the *share* of employment accounted for by

entrepreneurs evolved in accordance with model results.¹⁹ That is, aggregate employment is constructed based on the assumption that entrepreneurs’ actual share of employment in 2011 matches the model share produced by each respective experiment; for example, in the “Taste” counterfactual, entrepreneurs’ share of employment for 2011 is equal to 14.7 percent. Both counterfactuals begin in 2006 with entrepreneurs’ share of employment equal to 17.6 percent, as in the baseline scenario. The counterfactuals assume that between 2006 and 2011, entrepreneurs’ share of employment moves linearly toward its 2011 model value.²⁰ These counterfactuals can be thought of as a rough approximation of how aggregate employment would have evolved if the model experiments were the only forces driving employment. The counterfactuals are plotted in Figure 8. Observe that the “Taste” counterfactual almost exactly matches the path of aggregate employment, and the “LTV” counterfactual moves in a similar direction as aggregate employment. These are very rough, but they give a sense of the experiments’ quantitative implications.

¹⁹The assumption that the level of non-entrepreneurial employment evolves as in reality renders the counterfactual largely meaningless in the “Spread” and “All” cases, since in those cases the corporate sector is so heavily stressed.

²⁰Specifically, the counterfactuals are constructed as follows. Entrepreneurs’ share of employment was 17.6 percent in 2006. Let \hat{E}_t^i be counterfactual aggregate employment at time t for experimental scenario i . Let e_t be non-entrepreneurial employment at time t in the data. Let ω_t^i be entrepreneurs’ share of employment at time t for scenario i . Then $\omega_{2006}^i = 0.176$ for all i . Moreover,

$$\omega_{2011}^i = \begin{cases} 0.147 & \text{if } i = \text{“Taste”} \\ 0.168 & \text{if } i = \text{“LTV”} \end{cases}$$

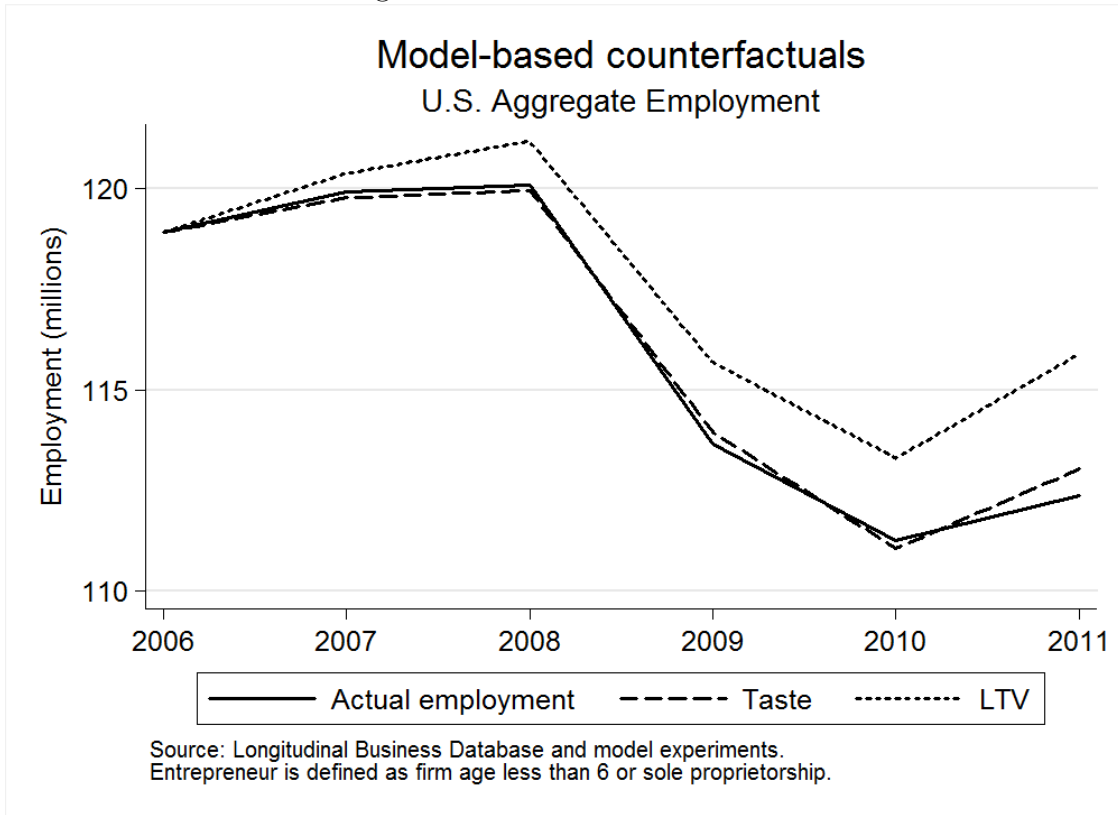
and

$$\omega_t^i = (t - 2006)(\omega_{2011}^i - 0.176)/5 + 0.176$$

Then the counterfactual aggregate employment is given by

$$\hat{E}_t^i = \frac{e_t}{1 - \omega_t^i}$$

Figure 8: Model counterfactuals



A primary finding of these exercises is that a housing crisis can have significant negative effects on entrepreneurial activity via the housing collateral channel, with the effects being quantitatively comparable to those seen in the Great Recession episode. Moreover, a broad financial crisis is not likely to reduce entrepreneurship as a share of total economic activity if its effects are felt by all firms.

4.2 Robustness experiments

In this section I describe some limitations of the experiments above and perform additional experiments to enhance my key results. I first conduct an experiment in which the house price falls as a result of an expansion of the housing supply instead of a taste shock. I then conduct partial equilibrium versions of the loan-to-value (“LTV”) and financial crisis (“Spread”) experiments, this time holding the house price constant. Finally, I relax the

assumption that entrepreneurs and corporate firms face the same credit spread, performing an experiment that allows me to determine the conditions under which a financial crisis can generate a large drop in entrepreneurial activity.

In the “Taste” experiment above, I obtained a decline in the house price by shocking housing preferences. An alternative way to induce a house price drop is to expand the housing supply. Table 7 reports key results from an experiment in which I expand housing supply by the amount required to generate a house price decline equaling that in the “Taste” experiment above. The “Baseline” and “Taste” columns repeat results from the Baseline and Taste scenarios described previously, while the “Supply” column provides results from the alternative experiment.

Table 7: Supply-driven house price drop

	Baseline	Taste	Supply
Housing supply H_s	2.5	2.5	3.2
q	1.40	0.96	0.96
r	8.10	8.10	8.10
w	0.99	0.99	0.99
Entrepreneurial output	0.34	0.28	0.30
Total output	1.49	1.48	1.48
Entrepreneurial employment	0.17	0.14	0.15
Entrep. share of employment	0.18	0.15	0.16
Startup employment	0.013	0.010	0.011
Startup share of employment	0.013	0.011	0.012

As shown in Table 7, to generate a supply-driven drop in the house price equivalent to the house price drop obtained in the “Taste” scenario, the housing supply must be expanded by about 28 percent. Equivalently, the average house size must rise from 2,500 to 3,200 square feet. This expansion of housing supply and accompanying decline in the house price is associated with lower entrepreneurial and startup activity, though the decline is not as large as in the taste shock experiment. Entrepreneurs’ share of employment falls from 17.6 percent to 15.9 percent. As with the taste shock experiment, the housing supply experiment is reasonably clean in the sense that aggregate output, the interest rate, and the wage are largely unaffected, so the decline in entrepreneurship is not driven by demand-side factors.

Moreover, the supply expansion experiment is equivalent to a partial equilibrium experiment in which the house price is exogenously set to $q = 0.96$.

In the experiments with the loan-to-value ratio (“LTV”) and the credit spread (“Spread”), the house price fell by 4 percent and 14 percent, respectively. Neither case matches the 31 percent decline seen in the taste shock experiment, but the lack of a constant house price in these experiments does limit the inference that can be drawn about the effect of house prices on entrepreneurship. Therefore, I conduct two partial equilibrium experiments. For the partial equilibrium version of the “LTV” experiment, I reduce the loan-to-value ratio from 0.92 to 0.78 but leave the house price as in the Baseline scenario. For the partial equilibrium version of the “Spread” experiment, I increase the credit spread from 0.009 to 0.037 but leave the house price as in the Baseline scenario. Results from the partial equilibrium exercises are reported in Table 8 (the results from the Baseline experiment are also reported on Table 8 for convenience).

Table 8: Partial equilibrium experiments

	Baseline	LTV	Spread
q	1.40	1.40	1.40
r	8.10	8.10	8.05
w	0.99	0.99	0.91
Entrepreneur output	0.34	0.32	0.35
Total output	1.49	1.48	1.37
Entrepreneurial employment	0.17	0.16	0.19
Entrep. share of employment	0.18	0.17	0.20
Startup employment	0.013	0.012	0.014
Startup share of employment	0.013	0.013	0.015

The partial equilibrium results are not qualitatively different from the general equilibrium results described in the previous section. The reduction in the loan-to-value ratio generates a reduction in entrepreneurial and startup activity, though the decline is less significant than in the general equilibrium version. This highlights the importance of the house price mechanism, which apparently is an important part of the reduction in entrepreneurship seen in the general equilibrium experiment. The rise in the credit spread again generates an

increase in entrepreneurial activity, but the increase is not significantly different from the general equilibrium version of the spread experiment. In general, the partial equilibrium exercises support the conclusions of the general equilibrium experiments.

A key conclusion of the main analysis in this paper is that a housing crisis can significantly reduce entrepreneurship, while a general financial crisis fails cannot (and can even increase entrepreneurial activity). The main driver of this result is the fact that entrepreneurial activity is irrevocably tied to household balance sheets, while corporate firms are independent of their owners' other assets. Since the credit supply friction—modeled here as an intermediation cost that gives rise to a credit spread—applies equally to all firms, it cannot disproportionately affect entrepreneurs directly. In the real world, it is likely that entrepreneurs and corporate firms face differential frictions even on the credit supply side. In terms of my model, this notion can be operationalized by allowing entrepreneurs and corporate firms to face a different credit spread.

In this general equilibrium experiment, I revise the model to include an additional intermediation cost or risk premium, again manifest in the form of a credit spread, that applies only to entrepreneurs. This results in entrepreneurs facing a higher capital rental rate than the corporate sector. In particular, the capital rental rates are now as follows:

$$r_c^k = \delta_k + \tau + r$$

$$r_e^k = \delta_k + \tau + \tau_e + r$$

where r_c^k is the rental rate faced by the corporate sector, r_e^k is the rental rate faced by entrepreneurs, and τ_e is the extra intermediation cost or risk premium that applies only to entrepreneurs. I can determine the potential of this difference in credit supply terms to explain the reduction in entrepreneurship by choosing a value for τ_e such that, in general equilibrium, entrepreneurship falls to the level seen in the housing taste/house price decline experiment described above (“Taste”). Table 9 reports results from this experiment on

the column labeled “Spread τ_e ”; results from the “Baseline” scenario and the “Taste” and “Spread” experiments are repeated for comparison.

Table 9: Entrepreneur-specific credit spread

	Baseline	Taste	Spread	Spread τ_e
τ_e	0.000	0.000	0.000	0.026
τ	0.009	0.009	0.037	0.037
q	1.40	0.96	1.20	1.20
r	8.10	8.10	8.00	8.14
w	0.99	0.99	0.91	0.91
Entrepreneurial output	0.34	0.28	0.35	0.26
Total output	1.49	1.48	1.37	1.37
Entrepreneurial employment	0.17	0.14	0.19	0.14
Entrep. share of employment	0.176	0.147	0.201	0.147
Startup employment	0.013	0.010	0.014	0.011
Startup share of employment	0.013	0.011	0.015	0.012

As Table 9 reports, the scenario in which entrepreneurs face an additional spread generates changes in house prices, wages, and output that are the same as the common-spread scenario. As targeted, entrepreneurial activity matches the low level of the housing taste/low house price scenario. The additional spread required to achieve this target is $\tau_e = 0.026$. In other words, a credit supply friction can generate the same reduction in entrepreneurship as the low-house price experiment provided that the increase in the credit spread faced by entrepreneurs is 2.6 percentage points or 70 percent larger than the increase in the credit spread faced by the corporate sector. Data on lending by commercial banks by loan size class suggests that such a large difference in the spread increase between small and large firms is implausible.²¹

²¹The Federal Reserve Board reports size-weighted interest rate averages by size class in its Survey of Terms of Business Lending. Consider the spread over 5-year Treasury Constant maturity (averaged annually for 2005 to 2011) for small loans (less than \$100 thousand) and large loans (greater than \$10 million). The difference between the small-loan spread and the large-loan spread ranges from 1.99 to 2.47 percentage points. In other words, the spread for small loans increases by less than 0.5 percentage points more than the spread for large loans, compared with 2.6 percentage points in the model. The results are similar if “large loans” are defined as being between \$1 million and \$10 million.

5 Conclusion

I review evidence consistent with a relationship between home values and entrepreneurship, with a key mechanism being the dependence of entrepreneurial activity on housing collateral. I construct a model characterized by rich financial frictions, a housing sector, and entrepreneurship. The model suggests that the disproportionate decline in entrepreneurial activity prior to and during the Great Recession was more likely to be caused by the housing crisis than the broad financial crisis. For a financial crisis to reduce entrepreneurship as much as a housing crisis, entrepreneurs must face a credit spread that is 70 percent higher than the spread faced by corporate firms. Recessions associated with large house price declines are likely to be “different” in the sense that low house prices can constrain entrepreneurs, with the potential for quantitatively significant implications for job creation (though I do not model this). This is a plausible mechanism for which there is growing evidence in the literature.

In the present study I have defined “housing crisis” and “financial crisis” in specific, narrow ways: A housing crisis is a contraction in the collateral value of housing (through a drop in either house prices or loan-to-value ratios), while a financial crisis is a positive, exogenous shock to credit spreads. In reality, these concepts are broad and interrelated. In the Great Recession, the housing crisis had large effects on banks and was a key driver of the financial crisis. I specify credit spreads and loan-to-value ratios exogenously, but both are equilibrium objects in the real world. For my purposes it is important to model the financial sector parsimoniously to allow for clean comparisons of the effects of various types of credit market stress on entrepreneurial activity.

With the caveat that this model necessarily simplifies key aspects of the financial sector, the model results may be thought of as a lower bound on the effects of housing collateral shocks on entrepreneurial job creation and on the effects of distressed entrepreneurs on the broader economy. One reason for this is that, in the model, the house price acts as a technology for converting output to housing, and a decline in the house price leaves more

output available for other uses. This can boost consumer demand, offsetting the pressures on entrepreneurial firms. Additionally, the model has a corporate sector that is not distressed by household collateral shocks. This corporate sector can compensate for low entrepreneurial output and labor demand, allowing households to continue to consume at high levels. The Great Recession was characterized by stress on large firms associated with, for example, credit supply restrictions and low aggregate demand. In reality and in my model, these effects can indirectly boost entrepreneurship through a labor market channel, but in reality the resulting increase in entrepreneurship is not likely to be characterized by the kind of high-growth entrants that drive job creation. Overall the model suggests that periods characterized by significant declines in home values are likely to be accompanied by lower entrepreneurial activity.

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Appendix A: Derivations

Financial intermediary profits

The financial intermediary's profit maximization problem is given by:

$$\max_{K_c, K_e, A_b, M_r} r^k(K_c + K_e) - r^a_{borrow} A_b + r^h q M_r - \delta_k(K_c + K_e) - \delta_h q M_r - \tau(K_c + K_e - A_b) - r A_s$$

subject to

$$K_c + K_e - A_b + q M_r = A_s$$

The first-order conditions follow:

$$\begin{aligned} K_c, K_e : & \quad r^k = \delta_k + \tau + r \\ A_b : & \quad r^a = \tau + r \text{ (for borrowers)} \\ M_r : & \quad r^h = \delta_h + r \end{aligned}$$

Substituting the first-order conditions into the profit function yields

$$Profits = r(K_c + K_e) - r A_b + r q M_r - r A_s$$

Substituting the financial market clearing condition given by (20) yields the result of zero profits.

Aggregate quantities

The aggregated variables used in market clearing conditions and the aggregate resource constraint are defined as follows:

$$A'_s = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) a'(s, a, h, z) \mathbb{I}_{a' \geq 0}(s, a, h, z) dz dh da \quad (24)$$

$$A'_b = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) a'(s, a, h, z) (1 - \mathbb{I}_{a' \geq 0}(s, a, h, z)) dz dh da \quad (25)$$

$$H' = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) h'(s, a, h, z) dz dh da \quad (26)$$

$$M_r = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) m(s, a, h, z) \mathbb{I}_{rent}(s, a, h, z) dz dh da \quad (27)$$

$$C = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) c(s, a, h, z) dz dh da \quad (28)$$

$$N_s = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) (1 - e(s, a, h, z)) dz dh da \quad (29)$$

$$N_e = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) n(s, a, h, z) dz dh da \quad (30)$$

$$K_e = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) k(s, a, h, z) dz dh da \quad (31)$$

$$Y_e = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) z k(s, a, h, z)^\alpha n(s, a, h, z)^\theta dz dh da \quad (32)$$

$$S_e = \int_a \int_h \int_z \mu(1, a, h, z) e(1, a, h, z) dz dh da \quad (33)$$

$$H_{adj} = \sum_{s=0}^1 \int_a \int_h \int_z \mu(s, a, h, z) \mathbb{I}_{h' \neq h}(s, a, h, z) h dz dh da \quad (34)$$

where $\mathbb{I}_{a' \geq 0}(s, a, h, z)$ is 1 for households with positive financial assets and 0 for borrowers, and $\mathbb{I}_{rent}(s, a, h, z)$ is defined by (10).

Aggregate resource constraint

The workers' budget constraint is given by (9), and the entrepreneurs' budget constraint is given by (12). These can be collapsed into a general budget constraint applying to all

households:²²

$$c + a' + q(h' - (1 - \delta_h)h) + \mathbb{I}_{rent} r^h qm + \mathbb{I}_{h' \neq h} \psi qh \leq zk^\alpha n^\theta - r^k k - wn - esv + (1 - e)w + (1 + r^a)a \quad (35)$$

Recall that $k = n = 0$ and $e = 0$ for workers, and $e = 1$ for entrepreneurs. Since utility is increasing in consumption, the budget constraint holds with equality for all households. Integrating both sides of (35) across the entire state space yields the aggregate resource constraint:

$$\begin{aligned} \sum_s \int_{a,h,z} (c + a' + q(h' - (1 - \delta_h)h) + \mathbb{I}_{rent} r^h qm + \mathbb{I}_{h' \neq h} \psi qh) dzdhda \\ = \sum_s \int_{a,h,z} (zk^\alpha n^\theta - r^k k - wn - esv + (1 - e)w + (1 + r^a)a) dzdhda \end{aligned} \quad (36)$$

Rearranging and using the notation for aggregate quantities given by (24)-(34) and substituting the financial sector's first-order conditions given by (17)-(19) simplifies the equation:

$$\begin{aligned} C + A'_b + A'_s + q(H' - (1 - \delta_h)H) + (r + \delta_h)qM_r + \psi qH_{adj} \\ = Y_e - (r + \delta_h + \tau)K_e + w(N_s - N_e) - S_e v + (1 + r)A_s + (1 + r + \tau)A_b \end{aligned} \quad (37)$$

Transforming (37) using the market clearing conditions described by (20) and (21) yields

$$\begin{aligned} C + K'_c + K'_e + qM'_r + q(H' - (1 - \delta_h)H) + \delta_h qM_r + \psi qH_{adj} \\ = Y_e - (r + \delta_k + \tau)K_e + wN_c - S_e v + K_c + K_e + qM_r + \tau A_b + r(K_e + K_c) \end{aligned}$$

The CRS technology of corporate production implies that $Y_c = (r + \tau + \delta_k)K_c + wN_c$; substituting this identity and the housing market clearing condition (22) into the aggregated

²²Optimal choice variables are functions of the state (*i.e.*, $a' = a'(s, a, h, z)$); for notational simplicity, I omit the parenthetical state list in this derivation.

budget constraint yields

$$\begin{aligned} C + K'_c + K'_e + \delta_h q H_s + \psi q H_{adj} + (\delta_h + \tau)(K_e + K_c) \\ = Y_e + Y_c + K_c + K_e + q M_r - (\delta_h + \tau)(K_e + K_c) - S_e v + \tau A_b \end{aligned}$$

Rearranging yields the aggregate resource constraint given by (23):

$$\begin{aligned} Y_e + Y_c - \psi q H_{adj} - \tau(K_c + K_e - A_b) - S_e v \\ = C + (K'_c - (1 - \delta_k)K_c) + (K'_e - (1 - \delta_k)K_e) + \delta_h q H_s \end{aligned}$$

Appendix B: Computational approach

Tauchen Method implementation

Consider a Pareto(x_m, η) process $\epsilon(t)$. Let z be an AR(1) process with $z(t) = \gamma z(t-1) + \epsilon(t)$.

Then discretize the z space into N_z equally spaced points, with $z_1 = x_m$ and

$$z_{N_z} = \frac{x_m}{0.001^{\frac{1}{\eta}}}$$

This is the value of z for which the CDF is equal to 0.999 (this value is necessarily arbitrary, since the domain of the random variable is unbounded). Using Tauchen's method, the probability of transitioning from z_i to z_j is given by

$$\begin{aligned} \pi_{i,j} &= \left(\frac{x_m}{z_j - \frac{z_j - z_{j-1}}{2} - \gamma z_i} \right)^\eta - \left(\frac{x_m}{z_j + \frac{z_{j+1} - z_j}{2} - \gamma z_i} \right)^\eta, \quad i \in \{1, \dots, N_z\}, \quad j \in \{2, \dots, N_z - 1\} \\ \pi_{i,1} &= 1 - \left(\frac{x_m}{z_1 + \frac{z_2 - z_1}{2} - \gamma z_i} \right)^\eta \\ \pi_{i,N_z} &= \left(\frac{x_m}{z_{N_z} - \frac{z_{N_z} - z_{N_z-1}}{2} - \gamma z_i} \right)^\eta \end{aligned}$$

For model tractability, reset transition probabilities to zero when $\pi_{i,j} < 0.00025$ and scale up all remaining positive probabilities accordingly. I set $N_z = 50$, with values for x_m and η given on Table 2.

Model solution algorithm

Solving for the model steady state (for a given parameter calibration) requires the following steps:

1. Make an initial guess for q , the house price.
2. Make an initial guess for r , the interest rate paid to savers.
3. Based on the corporate firm's optimality condition given by (8), use $w = (1-\xi)Z_c \left(\frac{r+\delta_k+\tau}{\xi Z_c} \right)^{\frac{\xi}{\xi-1}}$ to obtain the wage. The optimality condition also provides the corporate capital/labor ratio implied by the interest rate guess: $\frac{K_c}{N_c} = \left(\frac{Z_c \xi}{r+\delta_k+\tau} \right)^{\frac{1}{1-\xi}}$. Define this capital/labor ratio as X_{KN} .
4. Given the price vector (r, w, q) and using value function iteration, solve for the entrepreneur value function $v^{e=1}(s, a, h, z)$ and associated policy functions $x_{e=1}(s, a, h, z)$ for $x \in \{a', h', m, k, n\}$. Solve for the worker value function $v^{e=0}(a, h, z)$ and associated policy functions $x_{e=0}(a, h, z)$ for $x \in \{a', h', m\}$. For all points on the (discretized) state space, define $v(s, a, h, z) = \max(v^{e=0}(a, h, z), v^{e=1}(s, a, h, z))$, and define optimal policy functions as follows:

$$x(s, a, h, z) = \begin{cases} x_{e=1}(s, a, h, z) & \text{if } v^{e=1}(s, a, h, z) > v^{e=0}(a, h, z) \\ x_{e=0}(a, h, z) & \text{if } v^{e=0}(a, h, z) \geq v^{e=1}(s, a, h, z) \end{cases}$$

5. Make an initial guess μ_0 for the distribution of households, obtain $\mu' = \Psi(\mu_0)$, then iterate until convergence (according to desired tolerance) to fixed point μ^* .

6. Clear the labor market by defining

$$N_c = N_s - N_e$$

Then compute $K_c = X_{KN}N_c$. Define

$$K_c^* = A_s + A_b - K_e - qM_r$$

7. If $K_c = K_c^*$ (within chosen tolerance), then the financial market clears. If not, update the guess for r and return to step 3.
8. Compare aggregate housing demand $M_r + H'$ to housing supply H_s . If $M_r + H' = H_s$ (within chosen tolerance), all markets clear and the stationary state equilibrium has been obtained. Otherwise, update the guess for q and return to step 2.