ABSTRACT

Title of dissertation: ESSAYS ON FIRM DYNAMICS,
                           LOCAL FINANCIAL MARKETS,
                           AND THE BUSINESS CYCLE

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In this dissertation, I explore the relative importance of financial markets for businesses on both firm-level and aggregate outcomes. In my second chapter, I find empirically that local banking conditions are important for firm-level outcomes, in particular for old and small firms. This finding has two implications, each of which I explore in my second and third chapter, respectively.

First, the differential effect across firm age and size suggests sensitivity to financial conditions, or at least to certain financial mechanisms, is correlated with firm characteristics tightly linked with growth (age) and productivity (size). In the quantitative section of my second chapter, I develop a model that is consistent with this differential impact, while at the same time capturing the extreme sensitivity of young businesses to housing prices during the Great Recession.

Second, the importance of local banking markets is confirmation of the importance of geographic segmentation. While recent literature has focused on misalloca-

tion induced by financial shocks on misallocation *within* a geographic location, this finding suggests the potential for misallocation *across* geographies in the context of the United States. In my third chapter, I develop a framework for investigating the relative importance of misallocation within and across geographies, and I explore different types of shocks considered in the literature. I focus on the impact on labor productivity dispersion, which can be directly attributed to misallocation induced by financial frictions in my framework.

ESSAYS ON FIRM DYNAMICS,
LOCAL FINANCIAL MARKETS,
AND THE BUSINESS CYCLE

by

Glenn Jacob Blackwood

Dissertation submitted to the Faculty of the Graduate School of the
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Dedication

For Jamie, Parker, and Mirabel

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Finally, I would like to thank my wife, Jamie, whom I love dearly. You have earned this as much as I have. By the grace of God, we did it.

Disclaimer

Any opinions and conclusions expressed herein are those of the author and do not necessarily represent the views of the U.S. Census Bureau. All results have been reviewed to ensure that no confidential information was disclosed.

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Chapter 1:   Introduction

Is firm-level finance important for aggregate outcomes? To what extent are tighter credit conditions for businesses to blame for the severity of the most recent recession? The importance of finance on the firm-side for the downturn and recovery is much debated, and in many respects researchers are still grappling with the host of potential mechanisms responsible for the Great Recession. At the same time, recent literature has highlighted the fact that firms do not face homogenous credit conditions (Chodorow-Reich (2014), Greenstone et al. (2014)). This apparent segmentation in financial markets is important on several fronts. From an empirical perspective, this variation provides the potential for examining the impact of credit conditions on firm outcomes. Furthermore, the variation itself has implications for misallocation. If firms do not have the same access to financing, or are disproportionately impacted by credit shocks, this prohibits the reallocation of inputs. In particular, if credit conditions are correlated with firm characteristics, such as age, size, and productivity, then aggregate growth and productivity can be impacted.

In this dissertation, I explore the relative importance of business credit on both firm-level and aggregate outcomes. In my second chapter, I show empirically that local banking conditions are important for firm-level outcomes, in particular

for old and small firms. This finding poses several questions, which I explore in the remainder of my second chapter and my third chapter. First, the differential effect across firm age and size suggests sensitivity to financial conditions, or at least to certain financial mechanisms, is correlated with firm characteristics that are tightly linked with growth (age) and productivity (size). This could have implications for output and growth in the wake of the recession. In the quantitative section of my second chapter, I develop a model with two financial channels through which house prices work to influence firm outcomes. This model is consistent with this differential impact of local bank health, while at the same time capturing the extreme sensitivity of young businesses to housing prices during the Great Recession. I show that both channels are quantitatively important.

Second, the importance of local banking markets is confirmation of the importance of geographic segmentation. While recent literature has focused on misallocation induced by financial shocks on *within* a geographic location, this finding suggests the potential for misallocation *across* geographies in the context of the United States. In my third chapter, I develop a framework for thinking about the relative importance of misallocation within and across geographies, as well as the qualitative and quantitative implications of different financial shocks considered in the literature.

My second chapter contributes to the empirical literature on financial conditions facing US firms in the Great Recession by exploiting differences in local banking conditions across states prior to the crisis. I interact this variation with local house price shifts to proxy for the change in local banking conditions due

to housing market developments. Consistent with previous literature (Fort et al. (2012), Davis and Haltiwanger (2017)), I find that small businesses in general, but in particular young businesses (who are overwhelmingly small) were impacted disproportionately by house prices during the Great Recession period. However, the interaction between house prices and local banking conditions, which I call the bank balance sheet channel, is significant primarily for old and small firms. Taken together, the responsiveness of young firms to house prices (that cannot be attributed to local banking conditions) and the sensitivity of old and small firms to house prices through the bank balance sheet channel suggests that different transmission channels are important for different firm types.

With these results in hand, I then develop a general equilibrium model that is consistent with my empirical findings. Housing in the model is crucially related to two financial frictions. First, housing impacts bank balance sheets in a similar way to capital claims in the Gertler and Karadi (2011) and Gertler and Kiyotaki (2015) frameworks. Lower house prices generate a deterioration in bank balance sheets that in turn creates a larger spread between the lending rate in the borrowing rate. Essentially, house prices induce a credit supply shift through the financial intermediary. This is the banking channel. Second, similar to Decker (2015) housing acts a collateral for businesses, both for investment and working capital (labor). As house prices fall, the constraint tightens, restricting the ability of firms to borrow. This is the collateral channel. I find that the banking channel is important for old and small firms through its impact on the optimal scale of firms, while the collateral channel is particularly important for young firms, since they are more reliant on

housing collateral, as opposed to business capital, early on in their life cycle.

In addition to the heterogeneous impacts of banking conditions across the age/size distribution, the empirical work in my second chapter is also evidence of significant financial market segmentation in the United States during the crisis. Research has long noted potentially significant impacts of geographic segmentation in financial markets on business cycle fluctuations and long-run misallocation (e.g., see Morgan et al., Gopinath et al. (2015)). More recently, the impact of such financial market segmentation in the Great Recession was explored by Greenstone et al. (2014), although my results suggest larger effects. I contribute to this literature by constructing a model in which to analyze misallocation. Since the empirical work in my second chapter is silent on the exact mechanism influenced by local financial conditions, I explore different financial shocks that have been considered in the literature, highlighting differences in their impact on productivity dispersion.

In a setup similar to Hsieh and Klenow (2009), I develop a model with heterogeneous producers that impacted by various financial frictions, including collateral constraint, intermediation costs, and banking relationships (subject to exogenous separation). Importantly, the model has segmented islands, allowing me to examine differentials in financial frictions across geographies. Given the assumptions of constant returns and isoelastic demand, dispersion in marginal revenue products is equivalent to dispersion in distortions (or frictions) generated by the financial sector, and so therefore of misallocation. I evaluate the relative contributions of *within-* and *between-* island dispersion to overall dispersion (misallocation) in productivity. Additionally, I further decompose within-island dispersion into constrained dispersion,

relative means, and the extensive constrained/unconstrained margin.

Finally, while the empirical work in my second chapter indicates financial segmentation, it is silent on the nature of the segmentation and the mechanism through which firms are impacted by bank health. In particular, it does not indicate whether the extension or price of credit was impacted, both of which are considered in the literature. I address this issue as well in my third chapter by exploring several financial shocks and their implications for within-geography labor productivity dispersion. I show that some types of financial shocks have qualitatively and quantitatively different implications for dispersion, providing a testable implication in the data.

Chapter 2:   Same Shock, Separate Channels: House Prices and Firm

Performance in the Great Recession

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 US also experienced the largest financial crisis and recession since the Great Depression, which curtailed firms' ability to obtain credit (Ivashina and Scharfstein (2010), Adrian et al. (2013), Santos (2011)). Empirical work using firm data from the Great Recession suggests the impact of the ensuing recession particularly fell on young and small businesses (Fort et al. (2013)). Although this work has established that house price shocks disproportionately impact young and small firms, the reasons for this asymmetric effect are still largely undetermined (Davis and Haltiwanger (2017)). In this paper I explore the connection between local house prices and financial conditions, and how they interact to impact firms. I first document a local bank channel through which firms are impacted by house prices, focusing on how the impact varies by age and size. I then develop a heterogeneous agent general equilibrium model that is consistent with my empirical findings which features a bank credit supply channel and a collateral channel through which house prices influence firm outcomes. In both my empirical work and my quantitative

model, I find that the effect of the bank channel varies according to firm age and size, suggesting different channels may be important for different firm types.

In my empirical work, I build on two strands of the literature related to the Great Recession: research documenting financial distress driven by exposure to real estate markets in this period and the literature exploring the role of house prices in determining firm outcomes. The first strand links the housing crisis to the financial crisis (e.g. Cuñat et al. (2016)). The other line of research shows that house prices impacted young firms in particular (e.g. Davis and Haltiwanger (2017)). I contribute by connecting the variation in local house prices with local banking conditions in order to identify a financial channel through which house prices impact firm outcomes. I utilize the Longitudinal Business Database (LBD) from the Census Bureau, which covers the near universe of firms, in conjunction with FHFA house price data and banking sector data from FDIC call reports. 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 growth regressions. I find that young businesses (less than 5 years old) are sensitive to local house price variation, but the bank balance sheet channel explains little of their performance over the recession. On the other hand, I find meaningful effects of the bank channel on old and small businesses (at least 5 years old and less than 500 employees).

A theoretical framework that seeks to harmonize these findings with previous evidence of a disproportionate effect of house price shocks on young businesses requires multiple channels through which house prices impact firms. First, as identified in my empirical work, local financial conditions should interact with house

prices to impact firms, but not necessarily young firms. Second, to explain the disproportionate impact of house price shocks on young firms, a channel is needed that importantly influences businesses in their early stages. One mechanism that can potentially serve this role is a collateral channel. Recent research has found important effects of house prices on businesses through collateral and wealth channels, focusing primarily on young businesses and entrepreneurship (Robb and Robinson (2012), Adelino et al. (2013), Decker (2015)). If entrepreneurs can use their home equity as collateral for obtaining finance, then house price shocks can impact their ability to borrow by reducing the value of their collateral.

Therefore, in order to evaluate the aggregate effects of the housing crisis in a setting that can match these results, I develop a quantitative model in which housing appears on both bank and firm balance sheets. In this framework, bank net worth is dependent on the value of housing. As house prices fall, bank net worth deteriorates, tightening an internal constraint and contracting credit supply. Housing also appears as an asset for entrepreneurs, and is an important source of collateral for businesses to secure financing. Again, as house prices fall, collateral constraints tighten and reduce growth. In this sector, firms differ by age, asset holdings, and productivity, allowing me to investigate differential impacts across the firm distribution. For firms that have not acquired business capital (young firms), housing collateral will be important for growth.

This implies greater importance of the collateral channel for young firms, which explains almost all of the relative decline among young firms. However, the bank channel is also important for aggregate results, as the cost of labor and capital rises

with the interest rate increase generated by the banking sector. Furthermore, the model features an amplification mechanism through the mortgage rate, which also rises due to a contraction of credit supplied by the banking sector. This leads to a larger house price decline than would be observed in a case without endogenous tightening in the financial sector.
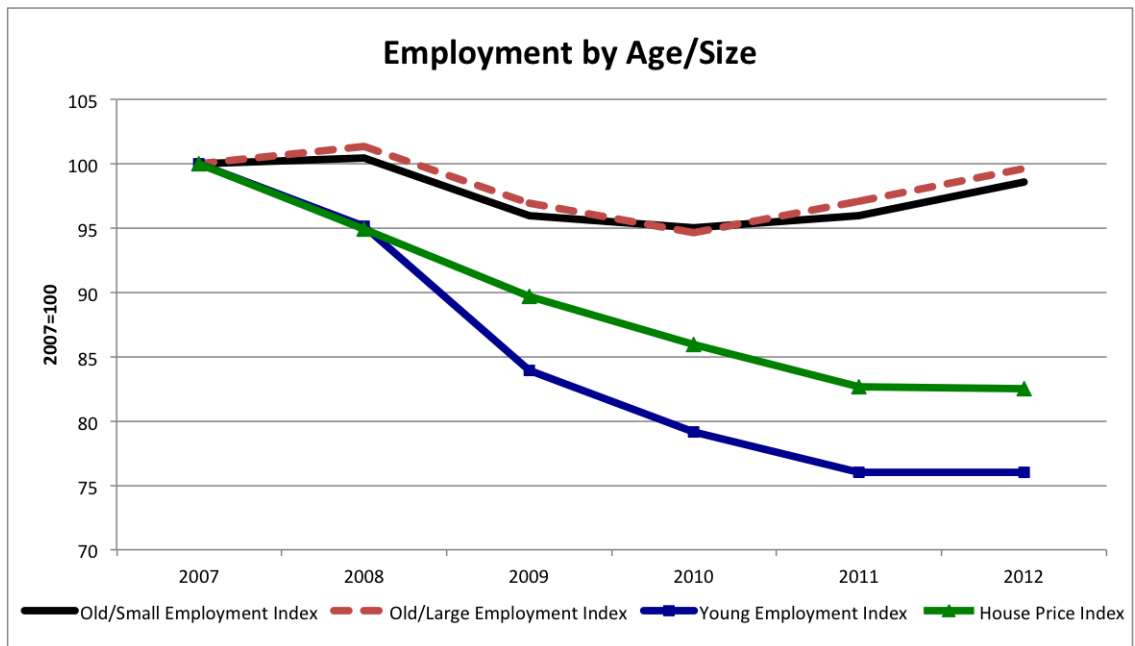
Figure 2.1: Employment in the Great Recession by Firm Age/Size (Source: Author Tabulations from the BDS)

In what follows, I discuss the literature in section 2 and my empirical analysis of the impact of the interaction between housing values and bank balance sheets on firm outcomes in section 3. I then detail the theoretical framework in section 4 before discussing my calibration, results, and counterfactuals in sections 5 and 6.

2.1 Background and Previous Literature

The expansive literature on business dynamics in the US emphasizes the relative importance of young businesses for growth. Young firms contribute disproportionately to job creation (Haltiwanger et al. (2013)), and 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 (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, while old small businesses contribute little to net growth on average, they make up a much larger share of employment than young businesses. My calculations from 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. Thus, shocks that impact old/small 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.

To highlight these points, in Figure 2.1 I use BDS data to plot employment among young firms (less than 5 years), old/small firms, and old/large firms (at least 500 employees, at least 5 years old). I index employment to 100 in 2007 for the sake of comparison. Furthermore, I plot FHFA house prices over the period, again

indexing to 100 in 2007.[1] From the plot, it is clear the impact of the Great Recession fell particularly on young firms, as employment at young firms was 24 percent lower in 2012 than it was in 2007. Employment at old businesses dropped by about 5 percent by 2010, regardless of size. Old/large businesses recovered to their pre-crisis level by 2012, while old/small businesses recovered, but not as quickly. The evidence presented in this paper suggests that local house prices impacted both young and old/small businesses substantially during the Great Recession, while old/large businesses were largely unaffected by local house prices. However, the mechanisms by which house prices impact firms differ.

This paper explores the local banking sector as one potential mechanism through which house prices impact employment. A great deal of research has been dedicated to documenting the extent of the credit supply contraction during the Great Recession. Ivashina and Scharfstein (2010) provide an early assessment of the contraction in the quantity of business lending during the financial crisis, and Adrian et al. (2013) provide further evidence of a contraction in bank lending in particular. Work by Santos (2011) suggests an increase in corporate interest spreads over the course of the recession. Much of this literature focuses on the corporate sector, while my work will take account of the near-universe of employer firms. In a similar fashion to my paper, some of the recent literature has focused on the impact

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[1]The peak for the quarterly series is Q2 of 2007 in the FHFA data. The date of the peak varies in other sources, and its path varies slightly, but in general the story is broadly consistent. The implications of this plot have furthermore been drawn out in other work (see Fort et al. (2013), e.g.).

of local housing markets on credit supplied by banks. Cuñat et al. (2016) focus on the effect of bank exposure to different housing markets on lending practices. Paixao (2017) documents the impact of house prices on bank capital and mortgage issuance using call report data over the course of the crisis. My empirical work differs in that I focus on house prices and their interaction with *pre*-crisis bank balance sheets in affecting real firm outcomes, rather than the impact of house prices on bank portfolios. I do this in order to capture bank "health" or "preparedness" prior to the crisis, rather than the endogenous response of bank health to the crisis, which could be correlated with firm performance. In this regard, my work follows that of Cole et al. (2012) which shows the predictive power of a set of bank balance sheet ratios on bank failure during this period. 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 on real outcomes.

Chodorow-Reich (2014) and Greenstone et al. (2016), which are closely related to this paper, document the impact of banking market variation for firm outcomes, concurring on a large decline in credit supply but differing on the real effect on employment. Similar to Greenstone et al. (2016), I utilize administrative data for the United States, but unlike their work, I exploit firm-level rather than county-level variation in order to explore underlying heterogeneity of credit supply effects across the firm distribution. On the other hand, Chodorow-Reich (2014) is primarily made up of relatively large firms. I am able to consider a more comprehensive set of firms that is more representative of both the age and size distribution. Both papers focus on large lenders as well, whereas my focus will be on "local" banks which are more

exposed to local house prices than large banks. As in Chodorow-Reich (2014), I emphasize differences across size and age, but note that the results differ from those observed in that paper, which could be attributed to the very different samples used. Greenstone et al. (2016) do not focus on hetereogeneous responses across the age and size distribution, as I do, and instead primarily consider county-level employment changes in response to their instrument for large bank credit supply.

This paper also builds on a long line of theoretical and quantitative work that explores the impact of financial frictions on real outcomes both over the long run and over the business cycle. This literature has posited constraints that fall directly on firms (e.g. Kiyotaki and Moore (1997), Cooley et al. (2004)), and frictions that inhibit the efficient intermediation of funds by the financial sector and create a shift in credit supply (Gertler and Karadi (2011)). My paper incorporates both types of frictions. Recent literature that explores the long-run impact of frictions in business credit markets in the form of a collateral constraint on the firm includes Buera et al. (2011), who attribute much of the difference in country-level development to financial frictions. Midrigan and Xu (2014) find in the context of their model that collateral-style constraints may not be as important, while Moll (2014) argues they may still matter along transition paths if shocks are persistent. Jermann and Quadrini (2012) explore the impact of a "credit crunch" in a DSGE framework, while Buera and Moll (2015) stress the importance of accounting for heterogeneity across firms (a feature of my model). Khan and Thomas (2013) also find quantitative importance of a credit crunch in a setting with decreasing returns to scale among heterogeneous producers and time-to-build assumptions in investment choices, two

characteristics of the environment facing firms in my model. In general, these papers consider shocks or changes to the collateral constraint itself. While my model features a tightening in collateral constraints, it is through housing values rather than an actual change in the collateral parameter.

Other models focus on the role of the financial sector in generating tightened credit conditions via an interest rate shock (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), Ajello (2016), and Decker (2015). Boissay et al. (2016) develop a model with frictions in the interbank market that produce increased costs of financing in crisis. My paper closely follows the work of Gertler and Karadi (2011) and Gertler and Kiyotaki (2015) by imposing an internal incentive constraint in the banking sector. Rather than expose the bank to capital quality or productivity shocks through equity claims on capital, as is done in those papers, this paper exposes banks to house price shocks through equity in housing. This connects the financial crisis to housing, generating an endogenous tightening in credit conditions in response to a house price shock.

In contrast to much of the theoretical literature, in my main experiment I do not shock any financial parameters, but rather change housing preferences and allow asset and collateral values to move endogenously as a result. Furthermore, I do not shock productivity, leaving the productive capacity of the economy unchanged. Still, the model generates a recession without either of these types of shocks, as falling housing values impact firms through the bank's incentive constraint and the

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collateral value of the housing stock. These results do not preclude the possibility of shifts in financial parameters or declines in productivity, but serve to highlight the potential of financial frictions in the firm and bank problems for amplifying shocks.

While other mechanisms through which house prices disproportionately impact young businesses have been proposed in addition to a bank channel (see Hurst and Pugsley (2015), for an example), I focus in my quantitative analysis on a collateral channel. Intuitively, if entrepreneurs rely on housing collateral early in their life cycle to obtain external finance, the impact of house prices could disproportionately impact them in the early stages of their business by tightening collateral constraints. Evidence for the importance of personal guarantees and collateral are apparent in both the Survey of Small Business Finance (SSBF) and the Kaufman Firm Survey (KFS). Avery et al. (1998) stress the importance of personal guarantees in obtaining finance in the SSBF, and to a lesser extent Home Equity Lines of Credit (HELOCs), for firms organized as limited liability corporations. For single proprietorships and partnerships, credit worthiness is implicitly tied to the net worth of the owner, while LLC's need to provide additional guarantees for personal wealth (and therefore home values) to be important. More recently, Robb and Robinson (2012) also stress the irrelevance of distinguishing between personal and business loans for non-LLC businesses in the KFS, but further note the prominence of personal loans in their sample, making up over a third of external financing among firms that borrow. Furthermore, they find that firms in areas with a higher housing supply elasticity (an instrument I use in my analysis) are able to borrow more, suggesting that more stable home values could supply a better source of collateral for firms. Adelino

et al. (2015) provide supporting evidence for this channel by showing that small businesses grew disproportionately in areas with larger house price increases over the boom. Furthermore they emphasize that these effects were particularly strong in industries that are more reliant on housing as collateral.

Given these findings, I incorporate housing as collateral value in a similar fashion to Decker (2015). This paper shows the importance of the impact of housing values on entrepreneurship and firm entry, while noting the importance of a credit spread shock in generating the aggregate outcomes observed in the Great Recession. My model differs in that entry is exogenous, but I allow credit spreads to respond to the housing shock, connecting both mechanisms to a single shock. Even without endogenous entry, the mechanism impacts young firm employment as entrants start with relatively little business capital, and are thus more reliant on their housing for collateral. As the firm accumulates business capital that can be collateralized, they can more easily weather shocks to housing collateral values.

2.2   Empirical Strategy

In what follows, I discuss my strategy for identifying a channel through which house prices affect financial conditions businesses face. In brief, the strategy considers the interaction of house price declines over the 2007-2012 period with bank balance sheet variables prior to that period. In particular, I explore whether indicators of the structure of the bank balance sheet in a state prior to the decline in house prices interact to influence firm outcomes like employment.

At the heart of the strategy are interaction terms of annual house prices changes with the 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 and influencing business outcomes. Then, the interaction of house prices with the pre-crisis bank balance sheets would serve as a proxy for changes in credit conditions.

In several specifications, I consider various interactions of house prices with bank balance sheets on employment outcomes at businesses distinguishing between "direct effects" (inclusive of demand, collateral, and other effects *not* working through the financial sector) and the "bank balance sheet" effect. I first discuss the data, and my construction of the dataset, before considering each specification in turn.

2.2.1 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.[2] Although the advantage of this paper is its coverage of the US economy, I ultimately must rely on geographic matching with banking data to characterize the lending environment of the firm. This relies on assumptions of financial geographic segmentation. Based on data from the Survey of Small Business Finances (SSBF), most small businesses borrow from nearby banks (Petersen and Rajan (2002), Brevoort et al. (2009)), and theoretical research has shown that distance to lender can matter for the acquisition of soft information (Boot and Thakor (1994), Agarwal and Hauswald (2010)). This, along with the evidence of banking relationships and their quantitative impact in normal times and over the business cycle (Petersen and Rajan (1994), Boualam (2015), Chodorow-Reich (2014)), makes it plausible that such segmentation is important. My results corroborate such a view, as local banking conditions appear to impact firms (in particular old/small firms).

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 and revenue as of March 12 of the year, making it possible to create employment and labor productivity measures on an annual basis. Furthermore, the dataset contains data on location, industry, and multi-unit status. Importantly, an age variable can be constructed. I focus on employment data for now, leaving the analysis of revenue productivity for later work.[3] In the analysis I

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[2]See Dinlersöz et al. (2017) for an example of a paper that 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 with data derived from the syndicated loan market.

[3]Further detail on the data construction process for the LBD, including cleaning, can be found

conduct, I focus on employment growth at the local level within a firm, splitting the sample by firm characteristics. In other words, 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. Consistent with this notion, I split the sample by *firm* age and size, highlighting differential impacts across the firm age/size distribution. To simplify exposition, I will refer to the unit of observation as an establishment outcome, although the reader should keep in mind the modification made to the concept.[4]

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 the entirety of insured institutions in the United States, providing detailed information on assets, liabilities, ownership structure, locations, and ownership history. The

in the data appendix of Haltiwanger et al. (2016).

[4]For each specification, I also report results using firm-level outcomes in the appendix. These results are broadly consistent. However, the presence of multi-establishment firms (in particular firms that branch across county borders) require an assumption on location of the firm. I choose the county based on modal employment, or the county with the largest share of employment at the firm. This likely introduces measurement error, as larger firms will be influenced by various house price shocks and financial conditions outside of those in the modal county. Focusing on establishment growth rates split by firm characteristics, as I do in the main text, solves this problem.

data are available on a quarterly basis, but I take averages over the year to create an annual dataset. I roll up banks to the ownership level, or bank holding company level. In order to make these data consistent with the theory of financial market segmentation mentioned above, I restrict myself to banks that only have branches in one state. Although I would like to be able to consider smaller markets than the state level, it is difficult to allocate assets for multi-county banks to their branches, and restricting myself to single branch banks would limit the sample too much. Therefore, I focus on single-state banks, which are still very common and provide me with enough variation over the business cycle to estimate the effect of local banking markets.

These banks are as small as several million dollars in assets up to large community banks of well over a billion dollars. Figure 2.2 provides an example of the relative importance of these banks, as they have accounted for roughly 10% of business loans over the last decade, but over 30% of small business loans. Given the theoretical background of financial market segmentation, small business lending is likely the more important function.[5]

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 local bank balance sheet structure across states. Next, I obtain house price data from the

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[5]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.

Single State Bank Commercial Lending
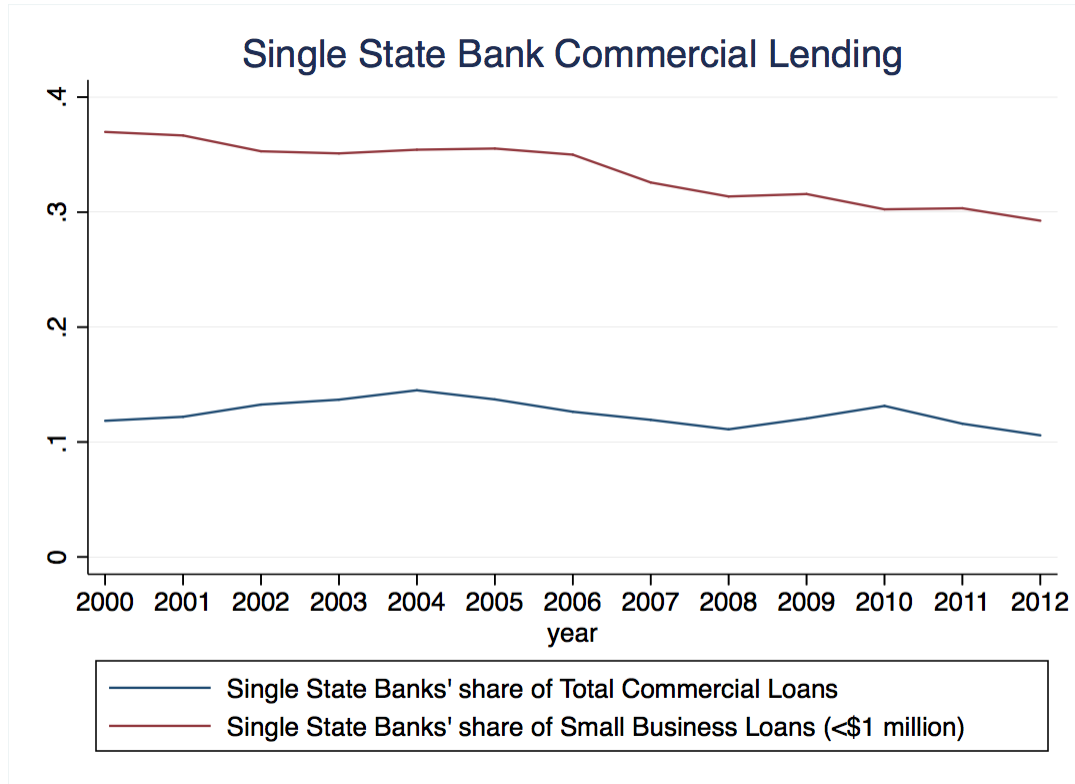
Figure 2.2: Importance of Single-State Banks in Small Business Lending (Source: Author's Calculations from the FDIC Call Report Data)

FHFA at the county level and unemployment at the county and state level from the BLS. Since my focus is on the period of national house price decline from the second quarter of 2007 to the second quarter of 2012, I use year-over-year changes in either the second quarter or June, depending on frequency, for each series. Finally I use instruments from Saiz (2010) on county housing price elasticities, which I discuss in more detail in the next section.

2.2.2 Empirical Framework

I develop an empirical model which captures the impact of house prices on firms through banks based on the shape of their pre-crisis bank balance sheet. I consider three approaches to capture the effect of house prices through a bank balance sheet channel. First, I consider 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 has the advantage of being easily interpretable and theoretically consistent with a model of deteriorating asset values induced by a decline in house prices. However, it is perhaps too narrowly focused on a single asset to truly characterize pre-crisis "bank health".

Second, I consider a two-stage setup where bank health is proxied by bank exit, which can be impacted by house price declines. Since bank health is a complicated multi-dimensional object that depends on several balance sheet factors, 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 an endogenous variable to firm performance, I develop a predictive model of bank exit in my first stage with bank balance sheet variables interacted with house prices on the right hand side.[6] In a sense, predicted

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[6]See the appendix for a list of the bank balance sheet variables used. I follow Cole and White (2012) in my choice of balance sheet variables, which include asset ratios, liability/asset ratios, and profitability measures. I use a snapshot in 2005, to maintain plausibility that the shock is unexpected, rather than a rolling window of asset ratios as the authors do. Furthermore, I create a state-level bank balance sheet, rather than an individual bank balance sheet, since ultimately my identification is based on geography.

bank exit acts as an index for the interaction of house prices with bank balance sheets, with the first stage generating the index in this two-stage setup.

Finally, I introduce a framework where the entire set of bank balance sheet interactions used as instruments in the bank balance sheet approach are directly included in the firm growth equation. This has the advantage of potentially capturing broader effects beyond bank exit or the interaction of house prices with one asset ratio. However, interpretability is more difficult in this case, as the cumulative effect of the regressors is the object of interest, not necessarily individual coefficients. Furthermore, it is difficult to instrument for house prices in such a setting, so I focus on the results from a simple OLS regression.

In what follows, I establish the correlation between housing values and firm performance briefly before discussing each of the above approaches in turn. However, one must also note the potential endogeneity in house prices. To account for this, I include additional instrumental variable regressions with the interaction of state-level unemployment rates interacting with county house price elasticities developed from Saiz (2010). This provides a plausibly exogenous instrument for house prices (supposing state-level changes in unemployment can be taken as exogenous to firm growth). Note that these 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.[7]

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[7]See the appendix for further discussion of alternative explanations which I seek to address in future work.

2.2.2.1 House Prices and Employment Growth

Before discussing the mortgage share approach, I first establish the correlation between house price growth and firm-level employment growth in the Great Recession. Specifically, I run a simple regression of the establsihment $e's$ 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]

$$\Delta Y_{e,t} = \gamma \Delta UR_{c,t} + \gamma \Delta UR_{s,t} + \beta_1 \mathbf{\Delta HPI_{c,t}} + \alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t} \quad (2.1)$$

I have included time effects δ_t and county fixed effects α_c, as well as the change in the county unemployment rate $\Delta UR_{c,t}$. I also include 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 $\Delta UR_{s,t}$ for completeness. 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 three categories: young (less than 5 years old), old/small (at least 5 years old and less than 500 employees), and old/large (at least 500 employees). In general, I expect there to be substantive differences between these groups, as older businesses have had time to form financial relationships, and larger businesses have access to broader capital

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[8]DHS growth rates are 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.

markets and furthermore may not be as sensitive to local conditions. The results
for the overall sample along with these breakouts are included in Table 2.1.

	Total	Young	Old/Small	Old/Large
OLS				
△ HPI	0.1317***	0.1744***	0.1017***	0.0179
	(0.0249)	(0.0350)	(0.0238)	(0.0132)
N	26,440,000	7,860,000	16,310,000	2,270,000
IV				
△ HPI	0.1944***	0.2150***	0.1298***	-0.0421
	(0.0431)	(0.0607)	(0.0476)	(0.0398)
N	18,520,000	5,700,000	11,290,000	1,530,000

Table 2.1: Employment Growth Regressions on House Prices. Note: Young < 5yo,
Old>=5 yo, Small <500 employees, Large >=500 employees; includes log(DHS denom-
inator), 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.

The results show a strongly significant relationship between house prices and
employment growth for establishments of young and old/small firms. The result
is also consistent with the notion that large businesses are less sensitive to local
conditions, as employment growth at large businesses is uncorrelated with house
price growth. I then 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 2.1, show an increased point estimate that is still significant for both young
and old/small.

2.2.2.2 Mortgage Share Approach

Given this relationship in my data, which is consistent with previous work connecting house prices to firm performance, I introduce an additional term that serves to highlight the influence of banking conditions on the impact of house prices on firm growth. This specification is a simple OLS regression similar to the previous specification, but with the addition of an interaction between house prices and the share of mortgages on state bank balance sheets.

$$\Delta Y_{e,t} = \gamma \Delta UR_{c,t} + \gamma \Delta UR_{s,t} + \beta_1 \mathbf{\Delta HPI_{c,t}} + \beta_2 \mathbf{\Delta HPI_{c,t}} * \mathbf{MTG_{s,2005}} \qquad (2.2)$$

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

Intuitively, it makes sense that a bank with a high mortgage ratio would be more sensitive to house price changes, so simply including the interaction with mortgage ratios could highlight the effect of bank balance sheets. To get a sense of the underlying variation in the data (although I subsequently normalize all bank balance sheet variables to make them mean zero for interpretation purposes), in Figure 2.3 I plot state-level mortgage shares against state-level average house price declines over the 2007-2012 period. There is a fair amount of variation in mortgage shares. Some states have local banks with 30 percent of their assets allocated to mortgages, while other have very little.[9]

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[9]Interestingly, the four states with the largest house price declines have some of the lowest mortgage shares, and the overall relationship appears to be negative. While a lower mortgage share would theoretically make these states less susceptible to house price declines, keep in mind
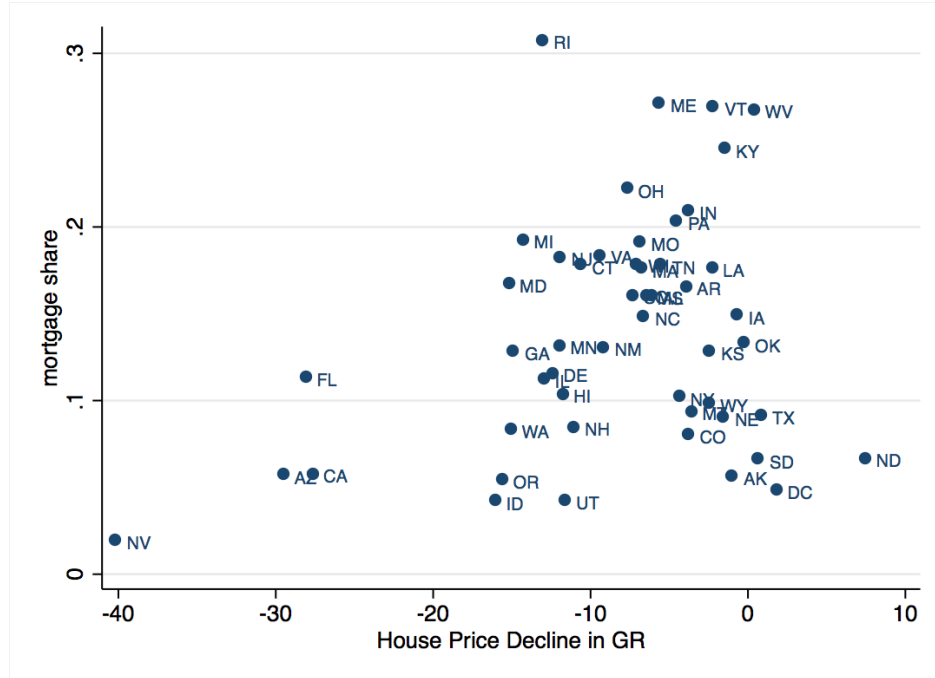
Figure 2.3: Pre-Crisis Mortgage Share and 2007-12 HPI Growth (Source: FHFA and FDIC)

Table 2.2 presents the results from the regression. 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

that mortgages are generally positively correlated with better bank health. Furthermore, bank health is a complex object, and a single component of bank balance sheets will not likely capture the full extent of their preparedness for a crisis. Thus, while the mortgage share is useful due to its close connection with house prices, low mortgage shares do not necessarily indicate a bank that will weather house price shocks well.

prices and their interaction with pre-crisis mortgage share as endogenous variables regressed on the following instruments: (log) elasticity of county house prices η_c , the quadratic η_c^2, and the cubic term η_c^3 interacted with $\triangle UR_{s,t}$, as well as the interaction of η_c with $\triangle UR_{s,t}$ and the mortgage share $MTG_{s,2005}$, η_c^2 interacted with $\triangle UR_{s,t}$ and $MTG_{s,2005}$, and η_c^3 interacted with $\triangle UR_{s,t}$ and $MTG_{s,2005}$.

	Young	Old/Small	Old/Large
OLS			
$\triangle$ HPI	0.2618***	0.1512***	0.0155
	(0.0373)	(0.0184)	(0.0181)
$\triangle$ HPI*	0.1031***	0.0610***	-0.0032
MTG_RATIO	(0.0333)	(0.0203)	(0.0161)
N	7,860,000	16,310,000	2,270,000
Total IV			
$\triangle$ HPI	0.3275**	0.2767***	0.0340
	(0.1281)	(0.0859)	(0.0933)
$\triangle$ HPI*	0.1327	0.1522**	0.0937
MTG_RATIO	(0.1085)	(0.0771)	(0.0853)
N	5,700,000	11,290,000	1,530,000

Table 2.2: 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.

The results show a similar pattern to the tables in the previous section. House prices appear to have a large effect on young businesses in both the OLS and IV specification. Although the interaction with mortgage shares is significant 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/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 since those banks could be more sensitive to house price shocks. As before, it is apparent that old/large businesses are largely unaffected by house price shocks.

2.2.2.3 Bank Exit Approach

Bank health is a complicated object, and a single variable will likely not capture this multidimensionality. As a step toward incorporating a broader scope of bank balance sheets, I consider the propensity for banks to exit in a particular year as an indicator of overall bank health in the state. That is, 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:[10]

$$\Delta Y_{e,t} = \gamma \Delta UR_{c,t} + \beta_1 \mathbf{\Delta HPI_{c,t}} + \beta_2 \mathbf{BE_{s,t}} + \alpha_c + \delta_t + \tau_i + size_{e,t} + \epsilon_{e,t} \qquad (2.3)$$

Again, I run this regression separately by young firms, old/small firms, and old/large firms. 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 2.3 seem to confirm

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[10]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.

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, as establishments of young firms appear more sensitive to the direct effect of house prices, while establishments of old/large firms are largely unaffected. The bank exit effect seems to impact establishments of old/small firms, but the coefficient for establishments of young firms is not significant.

Clearly bank exit is endogenous to firm performance, so I need to instrument bank exit. As discussed before, I use the county-level housing price elasticities from Saiz (2010) to instrument for house prices in the second section of Table 2.3. I instrument bank exit with the interaction of house prices with bank balance sheet variables of state banks in 2005. These variables have been shown in Cole and White (2012) to predict bank failure, and fixing the time frame in 2005 plausibly resolves endogeneity issues between outcomes in the Great Recession and bank portfolio choices. Since these indicators are fixed across time, I interact them with house prices to obtain predicted bank exit share via house prices interacting with pre-crisis bank balance sheets. Since house prices are controlled for in the main regression, what is left can only be attributed to the influence of house prices on bank balance sheets. These results are displayed in the bottom of Table 2.3. When either house prices or bank exit is instrumented, the main results remain. The point estimates for the instrumented variable typically increases in absolute magnitude, while the standard errors also increase.

One might be concerned about the exclusion restriction here: does the inter-

	Young	Old/Small	Old/Large
OLS			
$\triangle$ HPI	0.1740***	0.1003***	0.0177
	(0.0351)	(0.0236)	(0.0132)
Bank Exit	-0.0107	-0.0456***	-0.0109
	(0.0209)	(0.0118)	(0.0137)
N	7,860,000	16,310,000	2,270,000
Instrumented HPI			
$\triangle \hat{HPI}$	0.2146***	0.1294***	-0.0425
	(0.0606)	(0.0472)	(0.0398)
Bank Exit	-0.0185	-0.0504***	-0.0113
	(0.0229)	(0.0134)	(0.0169)
N	5,700,000	11,290,000	1,530,000
Inst. HPI & Bank Exit			
$\triangle \hat{HPI}$	0.1765***	0.1374***	-0.0519
	(0.0437)	(0.0402)	(0.0361)
$\hat{BE}$	-0.0524	-0.2304***	-0.1941*
	(0.1803)	(0.0874)	(0.1038)
N	5,700,000	11,290,000	1,530,000

Table 2.3: 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.

action of house prices with bank balance sheet variables only impact firm growth through bank exit? Deterioration in bank health due to house price decline could cause a decline in lending but not necessarily an exit. That is, the effect of house prices on local financial conditions is broader than bank exit. In the next section, I consider an approach that would account for broader effects.
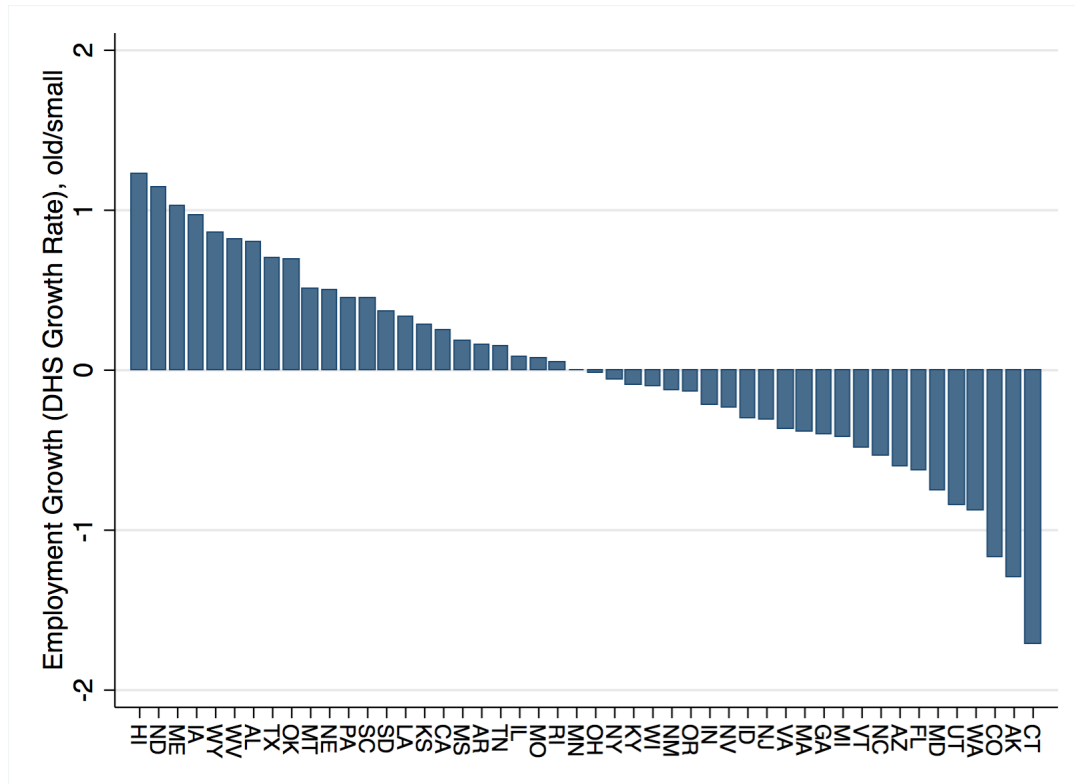
Figure 2.4: Multivariate Regressions: Effect of 5% HPI Change on DHS Employment Growth via Bank Effect, Old/Small Firms

2.2.2.4 Full Bank Balance Sheet Approach

As discussed before, bank health is a multi-dimensional object, and one balance sheet variable will likely have a hard time capturing such a complex object.
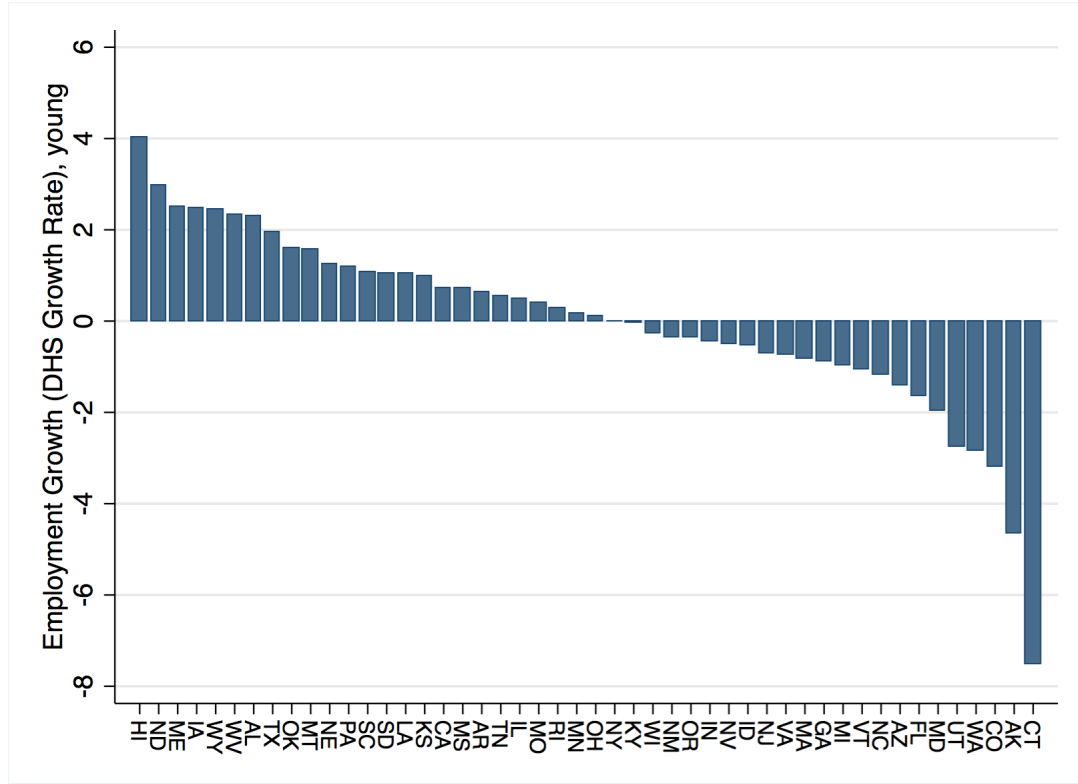
Figure 2.5: Multivariate Regressions: Effect of 5% HPI Change on DHS Employment Growth via Bank Effect, Young Firms

Rather than restrict myself 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 (given the average house price decline in the state), distinguishing between the direct effect of house prices and the effect of the interac-
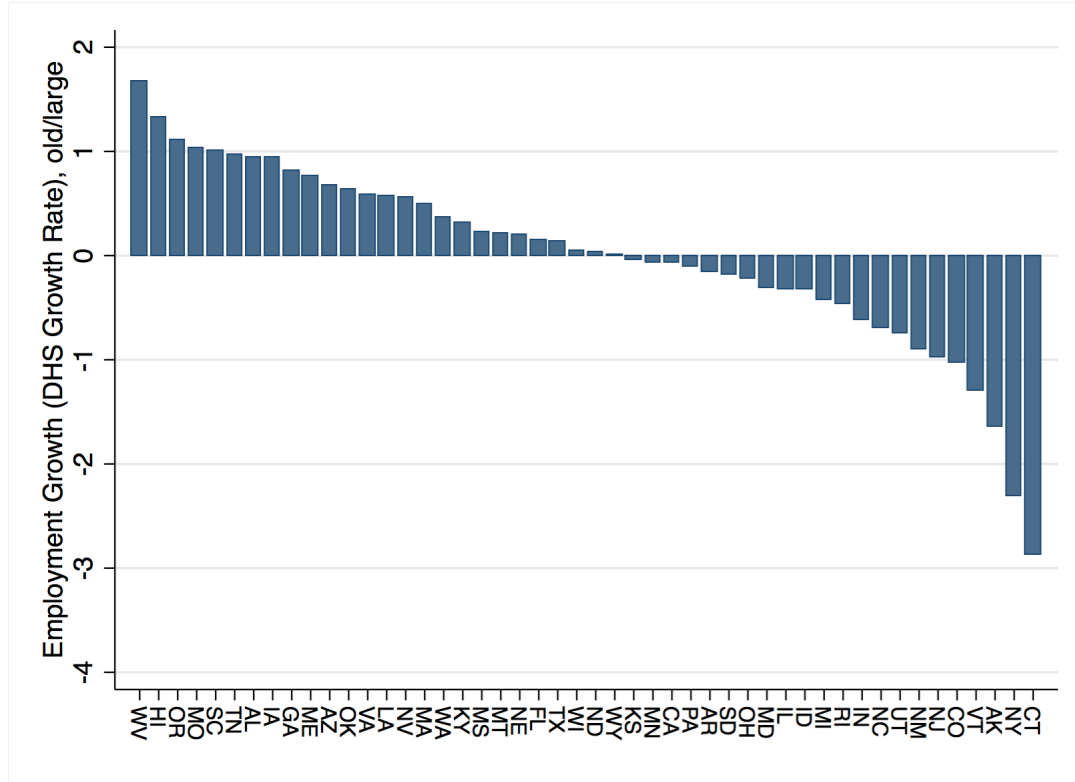
Figure 2.6: Multivariate Regressions: Effect of 5% HPI Change on DHS Employment Growth via Bank Effect, Old/Large Firms

tion terms. 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. Figures 2.4, 2.5, and 2.6 show the impact of the bank balance sheet interaction effect on the youg, old/small, and old/large groups, respectively.

In general, these graphs show a picture of substantial impacts of the bank balance sheet effect for both all categories of firms. However, they appear qualitatively different. Focusing on the old/small group, the figure shows that bank balance sheets vary enough to produce notable differences across states: some states' bank
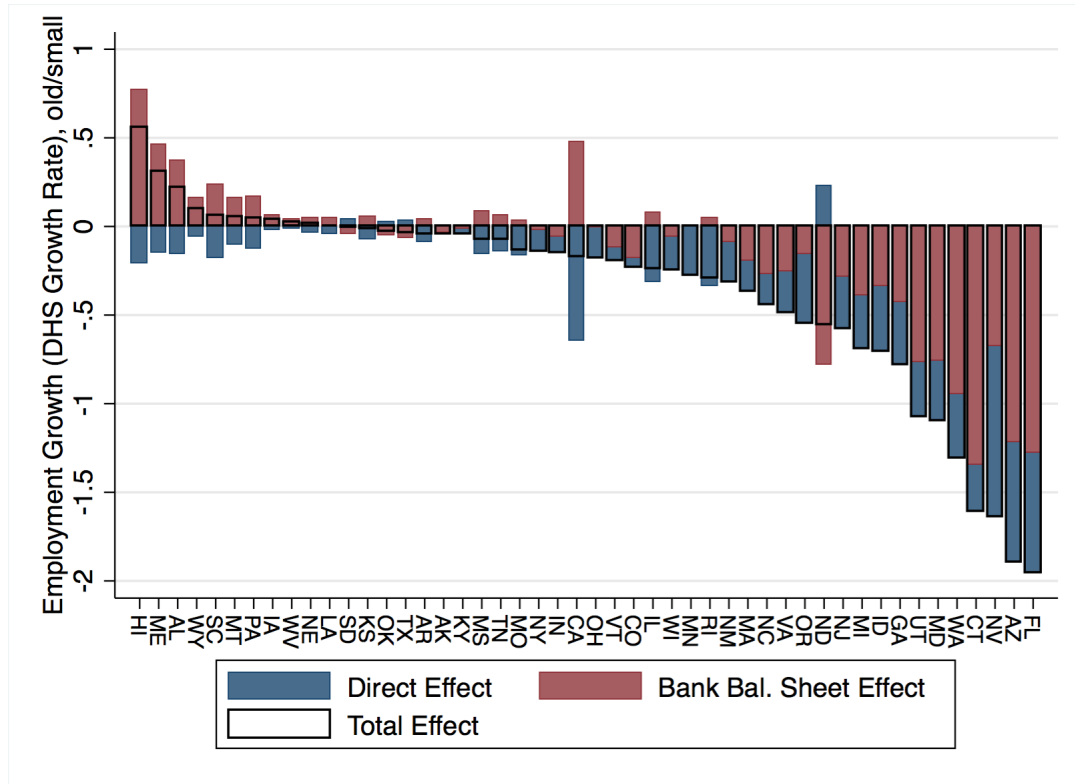
Figure 2.7: Multivariate Regressions: Effect of Average State-Level HPI Change on DHS Employment Growth, Old/Small Firms

balance sheets create an "amplification" effect as employment declines by an additional 1 percent, and some state bank balance sheets mitigated the effect of house price declines by as much as 1 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.

Among young firms, the range is even larger, with some states reporting a predicted decline of over 2 percent. However the largest significant effects seem to mitigate the effect of house price declines, with several predicted increases of over 8 percent due to the decline in house prices. Given these are concentrated in states
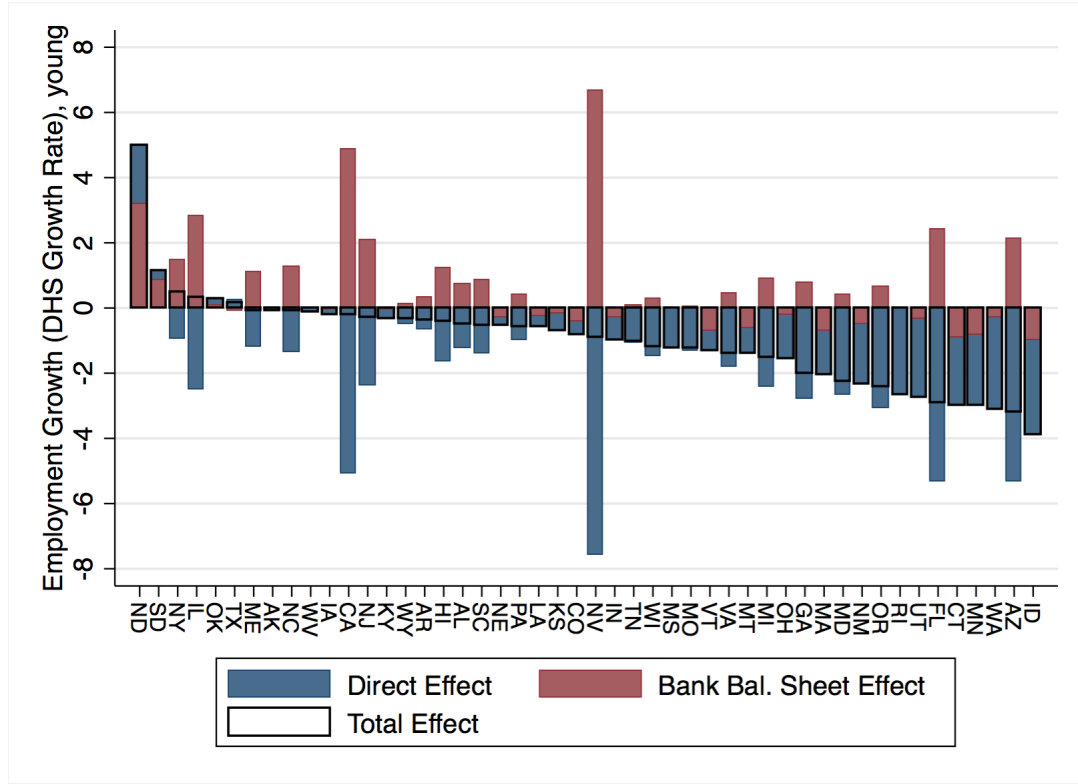
Figure 2.8: Multivariate Regressions: Effect of Average State-Level HPI Change on Firm-level DHS Employment Growth, Young Firms

with large declines, this seems unlikely.

The response of establishments at old/large firms looks similar to establishments of old/small firms in terms of magnitudes, but like young firms, the bank effect is mitigating much of the impact of house prices on establishments in states with large house price declines. Thus, while bank balance sheet effects vary more across states for young firms, and there are similar effects across the size dimension for old firms, the bank effect doesn't seem to be contributing as much to the decline in employment in states with large house price declines for the young and old/large groups.

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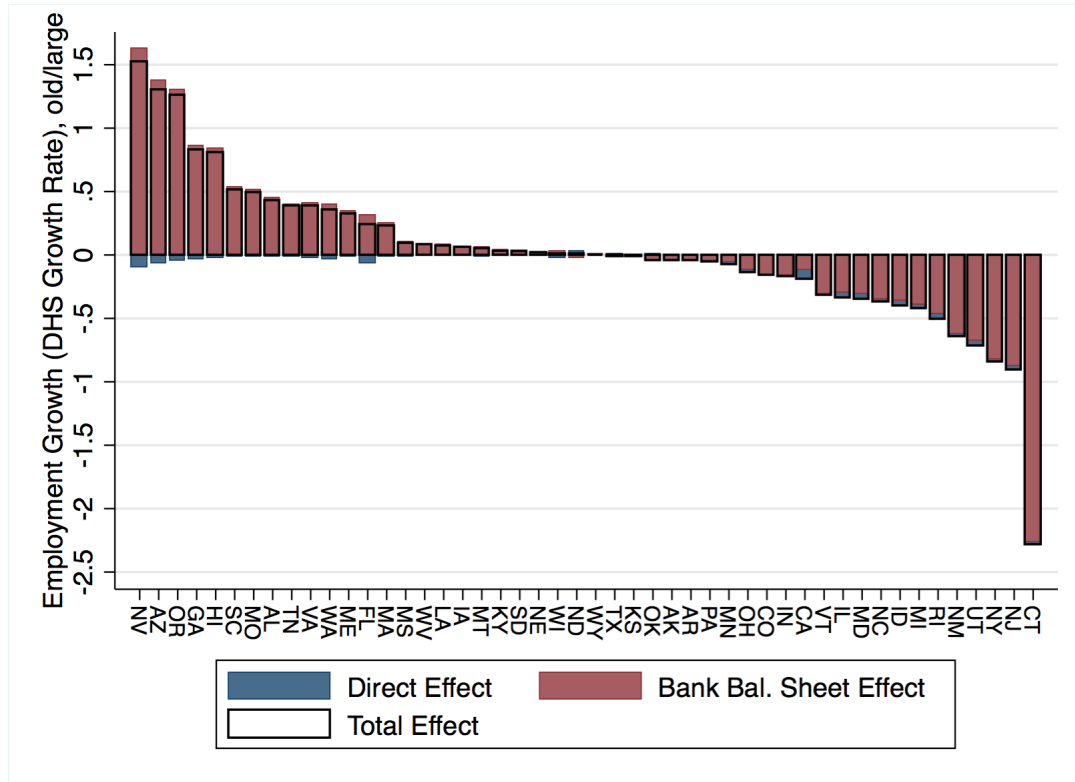
Figure 2.9: Multivariate Regressions: Effect of Average State-Level HPI Change on DHS Employment Growth, Old/LargeFirms

To demonstrate this, I show in Figures 2.6, 2.7, and 2.8 both the effect of the change in house prices via the interaction term (called the Bank Balance Sheet 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.[11]

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[11]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

From these figures, it is more clear that bank balance sheets seem 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 bank balance sheet effects of house prices are larger, the bank balance sheet effect appears to have less explanatory power for overall growth in employment among young firms due to house price declines over the Great Recession and subsequent recovery. Among establishments at old/large firms, the effect of house prices is largely transmitted through the bank channel, but again it does not seem to be contributing to declines in the hardest hit states.

Overall, the results consistently point to a significant impact of local bank balance sheet structure on the sensitivity of old and small businesses to house price changes. I interpret this as a local bank channel that is reflective of house prices impacting old/small firms through local financial intermediaries. The effect of this channel on young firms appears to be weak at most, although house prices are still important for predicting firm outcomes. In my theoretical work, I seek to construct a model to match these facts, focusing on the differential impact of house prices on young vs. old firms.[12]

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 39.0 (p-value of 0.000) for young, 22.3 (0.000) for old/small, and 9.91 (0.002) for old/large. Considering only the interactions, the joint F-stat is 27.1 (0.000) for young, 19.0 (0.000) for old, and 9. (0.002) for old/large.

[12]In the appendix, I note some alternative explanations for the relationships I demonstrate. One potential interpretation is to suggest that the young/old distinction is driven by differential demand. I show in appendix D the results of similar regressions for the tradable sector defined

2.3 General Equilibrium 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. The relevant channels for house prices to impact firms, in addition to general equilibrium effects, will be a bank credit supply channel and a collateral channel. As part of the exercises I undertake to evaluate the importance of each channel, I 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.

The model consists of three types of agents: a representative household; a continuum of entrepreneurs/ producers who are heterogeneous in productivity and portfolio holdings; and financial intermediaries, which I call banks, who take deposits from the household and lend to entrepreneurs.

The representative household is fairly standard. It consumes nondurable goods and housing services both from owner-occupied houses and rental housing. It saves in the form of bond, which serves as deposits for the bank. This sector will be the source of the housing shock, as house prices will fall due to a shift in household preferences.

in Mian and Sufi (2014). I find that house prices have an important impact on young firms even in this sector, consistent with evidence in Davis and Haltiwanger (2017). Furthermore the bank balance sheet channel is present under the bank exit specification for these sectors. I do not find a significant impact of the mortgage interaction for any firm age/size group.

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 their life cycle. 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. Their constraint is dependent on their assets, since they are able to borrow against their own capital and, crucially, household equity in housing. Additionally, there are limited life cycle dynamics in that entrepreneurs are born exogenously and are subject to an exogenous death shock, which are standard. New entrants are endowed with business capital κ_e, guaranteeing them the ability to produce in the first period.

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 endowment and its ownership of rental housing as an asset on its portfolio. Banks are endowed with the replacement level of housing δ_h and liquid wealth, which they can leverage to fund asset purchases. However, an internal incentive compatability constraint limits the extent to which they can leverage their assets. In response to a housing shock, the bank will have lower initial net worth, based on its endowment, and its preferences for owning housing will change. This leads to shifts in portfolio choice and a tightening in the constraint, which in turn leads to tighter lending conditions for the household and businesses. In addition to the direct impact this has on firm output, it also drives up mortgage rates, leading to a sharper decline in house prices and even tighter

conditions.

In what follows, I describe household problem, the entrepreneur problem, the final goods producer's problem, and the financial intermediaries' problem in turn before defining an equilibrium.

2.3.1 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 buying bonds B at price q which implies a deposit rate r in for the banking sector. Furthermore, each household must borrow to finance housing expenditures. Formally, the household problem is given by the following:

$$\max_{\{L_t, H_{t+1}, H_{R,t+1}, B_{t+t}\}_{t=0}^\infty} \sum_{t=0}^\infty \beta U(C_t, 1 - L_t, H_t, H_{R,t}) \tag{2.4}$$

s.t.

$$C_t + q_{t+1}B_{t+1} + R_{h,t}H_{R,t} + q_{h,t+1}(H_{t+1} - (1 - \delta_H)H_t) = B_t + w_t L_t + M' - (1 + r_m)\phi M \tag{2.5}$$

and

$$q_{h,t+1}(H_{t+1} - (1 - \delta_H)H_t) \leq M_{t+1} \tag{2.6}$$

In the budget constraint, we see that consumption (C_t), new bond purchases (B_{t+1}), rental housing $(H_{R,t})$, and new owner-occupied housing (H_{t+1}) are purchased with proceeds from previous period savings (B_t), wages $(w_t L_t)$. Additionally, mortgages M_t are required to purchase homes, and factor into the budget constraint. Consider

a case where preferences are additively separable and CRRA. Then the formula can be re-written recursively as:

$$V(B, H, M) = \max_{L, B', H', H'_R, M'} \frac{C^{1-\sigma_c}}{1 - \sigma_c} \tag{2.7}$$

$$+ \nu_l \frac{(1 - L)^{1-\sigma_L}}{1 - \sigma_L} + \nu_H (\epsilon H^{\frac{1}{1-\sigma_h}} + (1 - \epsilon) H_R^{\frac{1}{1-\sigma_h}})^{1-\sigma_h} + \beta V(B', H', M')$$

s.t.

$$C + q'B' + q'_h(H' - (1 - \delta_H)H) + R_h H_R \leq B + wL + M' - (1 + r_m)\phi M - q'B' \tag{2.8}$$

and

$$q'_H(H' - (1 - \delta_H)H) \leq M' \tag{2.9}$$

Optimization implies the following:

$$\nu_l(1 - L)^{-\sigma_L} = wC^{-\sigma_c} \tag{2.10}$$

$$\nu_H(\epsilon H^{\frac{1}{1-\sigma_h}} + (1 - \epsilon) H_R^{\frac{1}{1-\sigma_h}})^{-\sigma_H}(1 - \epsilon) H_R^{\frac{\sigma_h}{1-\sigma_h}} = R_h C^{-\sigma_c} \tag{2.11}$$

$$\frac{q'}{\beta} = \frac{(C')^{-\sigma_c}}{C^{-\sigma_c}} \tag{2.12}$$

$$q'_h(1 + r'_m)\phi_m = \nu_H \frac{(\epsilon H'^{\frac{1}{1-\sigma_h}} + (1 - \epsilon) H_R'^{\frac{1}{1-\sigma_h}})^{-\sigma_h}}{C'^{-\sigma_c}} \epsilon H^{\frac{\sigma_h}{1-\sigma_h}} + q''_h(1 - \delta_H)\beta(1 + r''_m)\phi_m \frac{C''^{-\sigma_c}}{C'^{-\sigma_c}} \tag{2.13}$$

The first equation governs the consumption-leisure tradeoff, the second governs the rental utility consumption tradeoff, and the third is the standard intertemporal Euler equation. Finally, the fourth equation represents the tradeoff between the cost of buying housing today and the benefit buying brings tomorrow: utility from housing and capital gains from price and borrowing rate changes. That is, higher expected prices tomorrow encourages borrowing today.

Assume for simplicity that $\sigma_L = 0$. Then, steady state versions of the above can be re-written to relate house prices to rental rates and the ratio of owner-occupied housing to rental housing:

$$q_h = \frac{R_h}{(1 - \beta(1 - \delta_H))(1 + r_m)\phi_m} \left(\frac{\epsilon}{1 - \epsilon}\right) \left(\frac{H}{H_R}\right)^{\frac{\sigma_h}{1 - \sigma_h}} \qquad (2.14)$$

Rental rates and interest rates will be pinned down with the addition of a banking sector and housing supply (which will be inelastic).

2.3.2 Entrepreneurs

In each period a measure 1 continuum of entrepreneurs produce a unique variety i of the intermediate good. These entrepreneurs can borrow for working capital and in an interperiod bond against current capital holdings k housing as collateral $q_h H_o$ which is taken as given from the household problem. There is a time to build assumption, in that capital is purchased at the end of a period but installed next period after the realization of idiosyncratic shocks. In addition to intraperiod working capital loans, the entrepreneur also has access to an interperiod bond, as the household does, which they can use to either save or borrow. The producer's problem is given by:

$$V(z_i, k, b) = \max_{c, \ell, k', h} ln(c) + \beta \zeta E \left[V(z_i', k', b')\right] \qquad (2.15)$$

The producer maximizes over consumption, labor, loans, and future capital subject to the following budget constraint:

$$c + k' + q(b')b' = p_i z_i k^\alpha h^{1-\alpha} + (1 - \delta)k + b - (1 + r_\ell)\ell \qquad (2.16)$$

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Where the first term on the right hand size is a Cobb-Douglas production function with constant returns multiplied by a product specific price. Capital evolves in the typical fashion: $k' = (1 - \delta)k + i$, where i is investment. Intertemporal debt b' is chosen at the end of the period, and ℓ is the amount of working capital loans taken out of the producer. The amount of wages paid to workers and investment for future periods must be financed by working capital (i.e., $\ell = wh$, where w is the wage rate and h is hours). Both intertemporal debt and intratemporal working capital loans are governed by a collateral constraint (note that intertemporal debt chosen in this period is constrained by next period's collateral constraint). I assume that there is a sense in which entrepreneurs are a part of the household, so they have access to homeowner equity. They can use some portion ξ_h of the home value owned by the household, which they use this as collateral to obtain finance in order to fund their business.[13]

$$(1 + r_\ell)\ell \leq \begin{cases} \xi(1 - \delta)k + \xi_h q_h(1 - \delta_h)H + b, & b \leq 0 \\ \xi(1 - \delta)k + \xi_h q_h(1 - \delta_h)H, & b > 0 \end{cases} \tag{2.17}$$

Furthermore, I need to specify an AR(1) process for the firm TFP process:

$$log(z_i') = \nu + \varphi log(z_i) + \epsilon \quad \epsilon \sim N(0, \sigma) \tag{2.18}$$

From this problem, we can see the impact of house prices and financial variables

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[13]I motivate this from evidence in Robb and Robinson (2012), who show that personal finance is an important source of external finance for entrepreneurs. However, roughly a third of financing comes in the form of a personal finance loan. Although the distinction for sole proprietorships and partnerships between personal and business loans is fuzzy, I take this as evidence that personal wealth is less "collateralizable."

on firm outcomes. The interest rate directly impacts both employment through working capital requirement, and the incentive to accumulate capital via the budget constraint in (2.16). This second effect in turn should lead to lower capital, which can potentially tighten (2.17) in future periods, thereby reducing credit demand. To the extent that house prices influence interest rates, which is established in the next section, they can shift the optimal scale for firms *and* effect the tightness of the collateral constraint, changing output and employment. Furthermore, house prices directly impact the collateral constraint, regardless of fluctuations in the interest rate. In my results section, I explore which of these effects matter for which firms, as well as aggregate outcomes.

With probability $1 - \zeta$ the firm dies, outstanding debts are collected, and remaining capital is scrapped. A new measure of $1 - \zeta$ firms are then exogenously born each period to keep unit mass. These new firms are allocated a small amount κ_e of capital as an endowment. They are able to borrow immediately against housing and capital endowments, and can produce in the first period of existence.

2.3.3 Final Goods Producer and Pricing

Additionally, revenue is not solely determined by production, but also prices. Prices differ since goods are differentiated. I use a monopolistic competition framework with the following aggregator.

$$Y = \int_i y_i^\rho di \tag{2.19}$$

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. Thus, the following is the problem for the final producer:

$$\max_{\{y_i\}} \int_i y_i^\rho di - \int_i p_i y_i di \qquad (2.20)$$

This will yield a pricing function given by (which is decreasing in own output since $\rho < 1$):

$$p_i = y_i^{\rho - 1} \qquad (2.21)$$

2.3.4   Banking Sector

To tractably represent the impact of a housing crisis on the banking sector, I implement a financial sector consisting of one-period banks in my framework. These banks are born at the end of the period when households and businesses are making savings/intertemporal borrowing decisions, which they facilitate by taking deposits and making intertemporal loans. They anticipate intratemporal lending in the next period (since there is no aggregate risk) and hold enough deposits overnight to meet the demand for working capital loans. After intratemporal loans are made and production takes place in the subsequent period, loans are repaid, depositors receive payments, and the bank consumes a fraction of profits before exiting.

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, which I assume is strictly positive. I model

this as a simple leverage constraint, where lending capacity depends on the bank's initial net worth and the interest rate. This constraint generates a positive spread between the interest rate faced by borrowers and the deposit rate. As the constraint tightens, there is potential for the interest rate to rise.

I assume banks are endowed with a fixed amount of housing, as well as transfers from profits of exiting banks. This assumption represents a world where bank net worth is inherently tied to housing markets, which is in line with the substantial exposure of local banks to housing markets seen in pre-crisis characteristics of bank balance sheets. Assets on bank balance sheets like mortgages and MBS can deteriorate in response to house price shocks, leading to lower net worth and reducing the capacity of the bank to lend. Since they only live for one period in this simple model, initial equity is entirely determined by their endowment, which in turn depends on house prices and performance of previous banks. As I will show, this initial endowment is important for determining credit supplied by the bank. Furthermore, banks are able to own rental housing, which leads to interactions between credit supply and their choices over housing assets.

This model is similar in spirit to that of Gertler and Karadi (2011) and Gertler and Kiyotaki (2015) in that banks are subject to an internal enforcement constraint. It differs in that part of their endowment stems from housing, representing exposure to housing in a static setting which could be the result of endogenous choices in a dynamic setting. Furthermore, by modeling one period banks, it is not possible for banks to alleviate the impact of their endowment by accumulating net worth over time. In that sense, the stark assumptions of this framework allow for changes in

credit supply in response to changes in housing values in a static setting that mimics the dynamics of the amplifier effect seen in this literature.[14]

2.3.4.1 Bank Problem

Banks make choices over a portfolio of assets. They lend to businesses, via intertemporal loans b and intratemporal 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. Since ℓ and b both face the same interest rate when $b < 0$, I define a as a generic business loan associated with interest rate r_ℓ that can either be intertemporal or intratemporal. The banks have linear preferences in end of life wealth, discounting it by χ which reflects the fact that some of their profits must be transferred to new banks. That is, at time t, the bank's objective is given by:

$$V = \chi n \tag{2.22}$$

This is subject to the constraint that net worth is equal to returns on rental housing h_R, mortgages m, and business loans a net of repayment to depositors:

$$n = (R_h + q'_h(1 - \delta_H))h_R + (1 + r_m)\phi_m m + (1 + r_\ell)a - (1 + r_d)d \tag{2.23}$$

As is standard in the literature, the bank has to fund assets out of deposits and initial net worth w_b

$$m + a + q_h h_R = d + w_b \tag{2.24}$$

[14]In future work, I hope to extend this to a dynamics setting, in which housing choices can be endogenously determined. Then, subject to a housing shocks, bank net worth will be impacted, leading to similar dynamics in Gertler and Karadi (2011) and Gertler and Kiyotaki (2015).

If there is no other constraint, the returns collapse to where there is no spread between the return on assets and the deposit rate. In this case, profits are zero on all intermediated funds, and zero in general unless the bank enters with some base level of net worth $w_b > 0$.

I assume the bank does enter with some wealth, and this endowment is key for relaxing an enforcement constraint. Conceptually, the bank manager can attempt to divert all the proceeds from assets and succeed with some probability $1/\theta$. Due to limited liability, depositors are by law only able to recoup the initial wealth of the banker in the case of diversion. To discourage such an attempt, the constraint requires that initial wealth of the bank is enough to cover the amount the bank manager can divert for his own purposes. This constraint is given by:

$$\theta w_b \geq (1 + r_m)m + (1 + r_l)a + (R_h + q'_h(1 - \delta_H))h_R \qquad (2.25)$$

This ensures that the value of repaying depositors is greater than the expected residual value of assets gross of interest the bank managers can capture if they decide to divert the proceeds. When tight, this constraint generates a spread between the lending rate and the borrowing rate.[15]

First order conditions imply an equalization of returns across firms:

$$R_b = \frac{(R_h + q'_h(1 - \delta_H))}{q_h} = (1 + r_m)\phi_m = (1 + r_\ell) \qquad (2.26)$$

I use this relationship to simplify the exposition of the bank problem.

[15]Gertler and Kiyotaki (2015) argue that one real world example of such an action by bank managers is that executives can pay themselves large bonuses in the absence of countervailing incentives which inhibit the intermediation process.

2.3.4.2 Timing, Endowments, and Aggregation

Since borrowing and lending in interperiod loans and deposit markets occurs at the end of the period, as dictated by the entrepreneurial sector problem, I assume the following timing. New banks are born at the end of the period and overlap briefly with old banks. Old banks receive payments and returns from assets, sell housing, and transfer wealth to new banks, while new banks receive their endowment, take deposits, buy/sell housing, lend to consumers and firms, and reserve some funds for intraperiod loans in the next period. I assume this happens frictionlessly, with transfers and purchases happening simultaneously. A clearinghouse construct could be used to obtain this, or a contractual framework in which transfers and obligations net out once banks, households, and firms have made decisions.

The determination of initial net worth w_b is important for the exposure of the banking sector to changes in housing. I assume it is a function of housing and a fraction $1 - \chi$ of previous aggregate bank net worth N (which is why net worth is discounted by χ in the value function: they only receive χ units). The housing endowment for the bank is a real share δ_h of the housing stock $H + H_R$. That is, they are endowed with the replacement stock of housing, independent of the valuation of housing. This stock is valued at q_h, so as q_h varies, so will initial net worth:

$$w_b = (1 - \chi)N + q_h \delta_h (H + H_R) \tag{2.27}$$

From this expression, it is apparent that as house prices fluctuate, and end-of-period aggregate net worth fluctuates, initial net worth will change. It is clear that housing

preferences will influence this expression through the housing endowment, but the fluctuation in aggregate net worth involves bank choices, and furthermore bank profitability will influence initial worth through transfers. Note that because there are measure 1 banks, each bank gets a share proportional to aggregate net worth of exiting banks. Likewise, aggregate initial wealth is equal to individual bank initial wealth: $W_b = \int_i w_b di = w_b$.

Aggregation of end-of-period profits across banks leads to a net worth accumulation equation of:

$$N = ((R_h + q'_h(1 - \delta_H))H_R + (1 + r_m)\phi M + (1 + r_\ell)A - (1 + r)D) \tag{2.28}$$

I can plug in the incentive constraint and the generalized return on bank assets to arrive at the following expression for net worth accumulation:

$$N = (R_b \phi W_b - (1 + r)(\phi - 1)W_b) \tag{2.29}$$

Where ϕ is the leverage ratio. This equation makes clear that net worth at the end of the period is dependent on initial wealth W_b. Initial wealth is in turn dependent on end-of-period net worth from exiting banks. This recursion creates an amplification effect as bank profitability leads to lower net worth, which impairs the ability of the bank to lend by tightening the constraint. Plugging in the definition for the endowment and simplifying, I arrive at the following equation for end-of-period bank net worth:

$$N = \frac{q_h \delta_h (H + H_R)\left((R_b - (1 + r))\phi + (1 + r)\right)}{1 - (1 - \chi)\left((R_b - (1 + r))\phi + (1 + r)\right)} \tag{2.30}$$

This equation shows that net worth is a positive function of house prices. Further-

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more, there is the potential for an amplification effect, as the term in the denominator is less than one. The ultimate change in end-of-period net worth, then, depends on the return on assets R_b and leverage ϕ.

Since N is dependent on W_b, returns to assets, and the volume of assets and deposits, it is difficult to determine what happens given a shock to house prices. Certainly W_b falls due to lower values of housing endowments, which could generate lower N, which in turn leads to lower W_b, and so on. This in turn tightens the constraint. However, this implies that leverage must fall and bank profits fall as well, which is an equilibrium outcome. In general, I find that interest rates must rise and bank leverage decline in response to a house price shock, leading to lower levels of lending under higher borrowing costs. Since depositors respond fairly elastically to a change in the interest rate (through reduced salaries), leverage falls, which is consistent with an increase in the interest rate.

2.3.5   Equilibrium

Define firm labor demand functions as $h(z_i, k_i, b_i)$ and bond demand functions $b(z_i, k_i, b_i)$ that maximize the firm's problem, given the pricing equation in the previous section. Let $\iota(z_i, k_i, b_i)$ be an indicator function that is equal to one if $b(z_i, k_i, b_i) > 0$, and 0 otherwise. Also, let N denote bank net worth in steady state, L denote labor supply and L_d denote total labor demand, and all other aggregate objects are defined as in previous sections. A stationary recursive competitive equilibrium in this economy, then, is a set of prices $\{w, \{p_i\}_{\forall i}, r_m, r_\ell, q, q_b, q_h, R_h\}$ that

clears the markets listed below.

Housing:

$$H_o + H_r = 1 \tag{2.31}$$

Mortgage:

$$M = qh(H - (1 - \delta_h)H) \tag{2.32}$$

Labor:

$$L = L_d = \int_i h(z_i, k_i, b_i) \, di \tag{2.33}$$

Bonds and Working Capital:

$$\int_i (1 + r_\ell) wh(z_i, k_i, b_i) \, di - \int_i b(z_i, k_i, b_i)(1 - \iota(z_i, k_i, b_i)) \, di = \tag{2.34}$$

$$N + \int_i b(z_i, k_i, b_i)\iota(z_i, k_i, b_i) \, di + OBD$$

Here, I posit there are outside investors that inelastically demand bonds OBD, which I calibrate in my quantitative section to foreign share of public debt. This dampens the response of savings to the interest rate, which moves quite elastically in steady state.

Aggregate initial net worth of the banking sector W_b follows the law of motion:

$$W_b = (1 - \chi)\left((R_h + q_h(1 - \delta_H))H_R + (1 + r_m)\phi M + (1 + r_\ell)A - (1 + r)D\right) + q_h \delta_h \tag{2.35}$$

where $A = \int_i q(b)(1 - \iota(z_i, k_i, b_i))b(z_i, k_i, b_i) \, di + \int_i wh(z_i, k_i, b_i) \, di$.

Define $\mu(z, k, b)$ as the distribution of firms across idiosyncratic productivities, capital stocks, and bond holdings. The distribution must satisfy:

$$\int_z \int_k \int_b \mu(z, k, b) \, db \, dk \, dz = 1 \tag{2.36}$$

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This object follows a law of motion Γ that is dependent on the exogenous processes specified in previous sections and optimal decisions of agents in the economy:

$$\mu'(z, k, b) = \Gamma(\mu(z, k, b)) \tag{2.37}$$

In a stationary distribution, $\mu(z, k, b) = \Gamma(\mu(z, k, b))$. Given a distribution μ, the aggregate capital stock K is given by:

$$\int_z \int_k \int_b k\mu(z, k, b) \ db \ dk \ dz = K \tag{2.38}$$

And total output Y is given by:

$$\int_z \int_k \int_b z^\rho k^{\rho\alpha} h(z, k, b)^{\rho(1-\alpha)} \mu(z, k, b) \ db \ dk \ dz = Y \tag{2.39}$$

Given Y, K, and L, along with the elasticity α I can define aggregate productivity as:

$$Z_{agg} = \frac{Y}{K^\alpha L^{1-\alpha}} \tag{2.40}$$

2.4   Calibration

In my calibration, I consider the set of moments described in Table 2.4. The first group of parameters I either take from the literature or I match moments by construction given data from the source listed.

The persistence of firm productivity φ is chosen from a range of estimates in the literature. There is substantial debate as to the best choice, so I pick a value that is central to potential estimates in Asker et al. (2014).[16] Likewise with depreciation δ, markups ρ, housing depreciation δ_h, and the discount factor β, I pick relatively standard values in the literature.

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[16]The evidence from Midrigan and Xu (2014) and Moll (2014) suggests that self-financing can

Calibration: Selected Parameters

Parameter	Value	Target Criteria/Source
ρ	0.9091	10 % Markups: Basu and Fernald (1997)
β	0.9615	4% deposit rate
ζ	0.9	10% death rate
φ	0.8	Asker et al. (2014)
δ	0.069	Cooper and Haltiwanger (2006)
δ_h	0.03	BEA
ξ_h	0.25	$\frac{\xi_h}{\xi} = 1/3$ Robb and Robinson (2012)

Table 2.4: Targets for Calibration. Note: Data sourced from Bureau of Economic Analysis (BEA), Federal Reserve Flow of Funds (FF), and the Bureau of Labor Statistics (BLS) are denoted as such. FDIC targets are based on my tabulations from state bank data.

I choose ξ_h to reflect the finding in Robb and Robinson (2012) that personal loans or home equity lines of credit were used for roughly a third of external finance in their sample. Thus, I pick a collateral value that is one half of the value for business capital. This perhaps reflects the relative ease with which banks can collect business assets vs. personal assets in case of default. Note that this value is dependent on the results in Table 2.5.

The 10 parameters in Table 2.5 are chosen jointly, targeting the moment listed from the literature. My model fits housing and debt-to-GDP data well. Given other values, bank leverage and house price-to-rent ratios can be matched almost exactly. Note that the latter is the mean of a range of values given in Garner and Verbrugge (2009) for pre-crisis housing markets in metropolitan areas. In the model, I target the standard deviation of investment using the average of t and $t - 1$ capital in the denominator. This mitigates the large variation produced by young firms.[17] I miss a little on the share of salaries to GDP, but this is with a fairly large value of $\alpha = 0.37$. I pick the value of ν_l to target employment to population in the data.

Finally, the financial variables are chosen to support a leverage ratio of 12, which is within a reasonable range cited by the literature (e.g. Gertler and Kiyotaki (2015) and Gertler and Karadi (2011)) , and a spread of 133 basis points implied by the rent-to-price ratio, which is also in a reasonable range given by the literature

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. Still, in future work I plan to perform some sensitivity analysis at values of, say, 0.7 and 0.95, to match the 10th and 90th percentile in Asker et al. (2014).

[17]Similar results can be found if entrants are excluded from the standard deviation calculation.

Calibration: Jointly Determined Parameters

Param.	Value	Target	Data	Model	Source
α	0.37	Labor Share	0.438	0.463	BEA
ν_l	2.4	EPOP (BLS)	0.670	0.694	BLS
σ	0.06	S.D. of (i/k)	0.337	0.347	Cooper and Haltiwanger (2006)
ξ	0.5	Debt/GDP	1.15	1.10	FF/BEA
κ_e	0.128	$\frac{Emp_0}{Emp_{mean}}$	0.253	0.246	BDS
ν_h	1.25	Housing/GDP	1.80	1.76	FF
ϵ	0.860	q_h/R_h	12	12	Garner and Verbrugge (2009)
θ	12.6	Bank Lev. ϕ	12	12	Gertler and Karadi (2011)
χ	0.52	spread implied by q_h/R_h	133 bp	133 bp	
OBD	0.413	Foreign-held debt	25%	25%	US Treasury

Table 2.5: Targets for Calibration. Note: Data sourced from Bureau of Economic Analysis (BEA), Federal Reserve Flow of Funds (FF), and the Bureau of Labor Statistics (BLS) are denoted as such. FDIC targets are based on my tabulations from state bank data.

(Phillipon (2015)). Given a target leverage ratio, I can calculate the θ that gives this at the individual level. Given the overall demand for loans, I can then calculate the w_b necessary for markets to clear.

2.5 Initial Steady State and Crisis

I now turn to comparative statics analysis that explores the response of the calibrated economy described above to a housing collapse. Specifically, I focus on a change in demand for owner-occupied housing ϵ. This allows for both a decline in house prices q_h and a fall in the price-to-rent ratio. Given a shock to ϵ, a fall in owner-occupied demand (and relative increase in rental demand) leads to a move from owner-occupied housing to rental housing. However, as the house price falls, the bank balance sheet tightens, leading to higher interest rates and a higher rent-to-price ratio, mitigating the decline in owner-occupied housing somewhat. In what follows, I choose a shift in ϵ that generates a house price decline of 22%, which is higher than the Great Recession average in the US according to FHFA. However, the national Case-Shiller index indicates a decline of 27% over the 2006-2012 period. My house price decline splits the difference. Additionally, I find that the decline in the owner occupied housing share in the model (from 0.67 to 0.57) is larger than the fall in the data (from roughly 0.68 to 0.64).[18]

Table 2.6 presents the new steady state results, with column 1 representing the initial regime and column 2 representing the new regime. The lower housing price

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[18]Other shocks, such as a shock to ν_h, housing supply and construction, or "outside" demand could have similar results. I plan to investigate alternative shocks in future iterations of the paper.

Alternate Regimes

	Baseline	Housing Crisis	Bank Channel Only	Coll. Channel Only
ϵ	0.860	0.590	0.590	0.590
Output	0.893	0.856	0.875	0.880
Employment	0.695	0.686	0.693	0.693
Capital	1.35	1.23	1.26	1.31
TFP	1.00	1.00	1.01	1.00
Debt	0.981	0.788	0.921	0.856
Owner-Occupied Housing	0.670	0.559	0.565	0.547
$q_h/q_{h,baseline}$	1	0.78	0.76	0.85
q_h/R_h	12	10.37	9.59	12
r_ℓ	5.33%	6.64%	7.42%	5.33%
w	0.596	0.574	0.565	0.583
ϕ	12	11.85	11.77	11.97
Bank Net Worth	0.150	0.131	0.126	0.150

Table 2.6: Alternate Regimes

generates an additional spread over the savings rate of 130 basis points–a substantial increase in borrowing costs for firms. This is also reflected in a decline in the price-to-rent ratio from 12 to 10.4. As mentioned above, there is a substantial decline in owner-occupied housing in line with the decline seen in the Great Recession. Business debt falls by over 20 percent, while employment falls by 1.2 percent. Capital stocks fall by 8.9 percent and output declines by about 4.1 percent. The reason for the disproportionate impact on capital appears to be induced by a drop in wages, which fall by 3.7 percent and mitigate the effect of rising interest rates on employment. TFP remains nearly unchanged. However, as we will see, lower capital stocks will imply lower output per worker.

It is worth noting what this crisis does *not* represent. Much of the literature has focused on shocks to collateral constraints ξ or an exogenous shock to financial intermediaries similar to a change in θ. In these experiments, I do not shock the financial parameters governing the model. Furthermore, there is no shock to aggregate TFP, as in Gertler and Kiyotaki (2015). A simple preference change creates an endogenous tightening on firm borrowing constraints and a shift in bank credit supply through falling house prices, without any shock to the real productive capacity of the economy. The tightening in both credit constraints and credit supply results from an endogenous response to household preferences and the resulting house price decline. To be sure, something along the lines of a shock to intermediation parameters, or to TFP, is likely in the context of the Great Recession. This paper, however, shows the potential for endogenous financial tightening to contribute to the decline in aggregate outcomes.
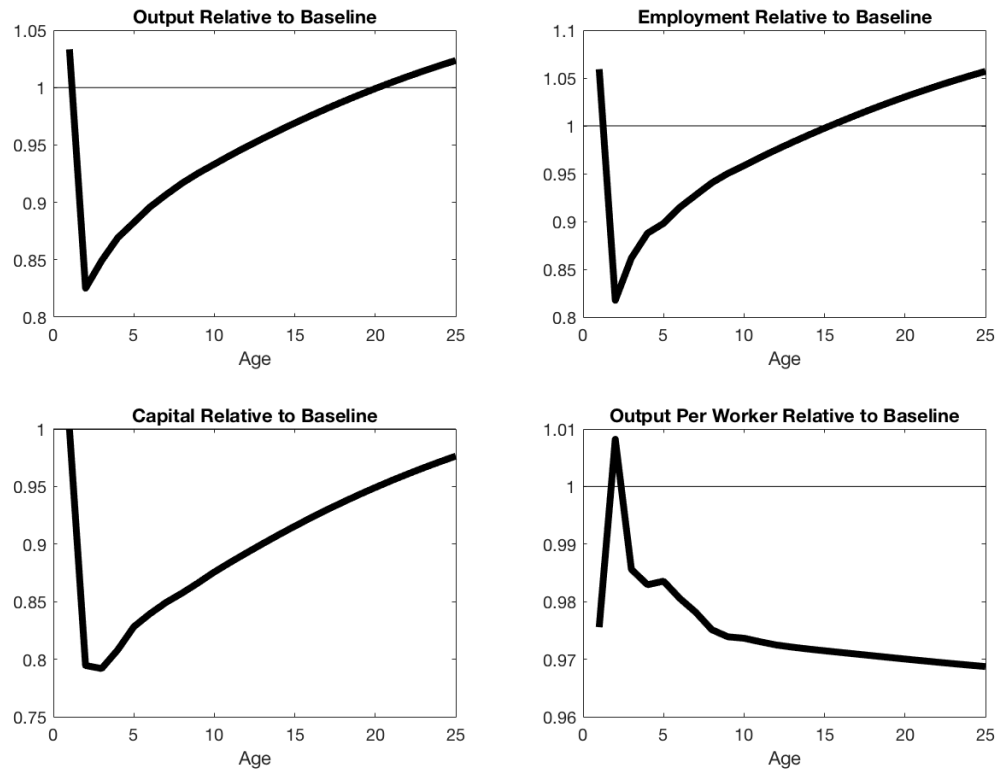
Figure 2.10: Comparison of High and Low House Price Regimes: Age Profile of Firms

How does this shock impact businesses at various points in their life-cycle? In figure 2.9, I plot the ratio of each series under the housing crisis regime to its value under the initial regime. One can think of this as the relative performance of firms under the crisis regime to their counterparts under the baseline regime. In general, I find businesses have lower output, capital, and labor inputs than their counterparts in the baseline, although eventually these values are higher for very old firms. Young firms are particularly impacted by the new regime, at points experiencing a decline of over 20 percent relative to the pre-crisis regime. This decline is reflected across output, employment, and capital. The change in output per worker is volatile in the

first few periods, as tighter constraints put upward pressure on output per worker with the decline in employment, but lower capital puts downward pressure on labor productivity. Eventually, lower capital accumulation over the life cycle of the firm begins to dominate and push down output per worker as labor recovers more quickly than capital.

2.6 Counterfactuals and Experiments

To tease out the relative importance of each channel, I undertake two sets of exercises. First, in order to assess the aggregate impact of each channel, I consider counterfactuals where one of the mechanisms is removed from the model. I pick parameters such that the initial steady state is identical to the baseline and then shock the economy with the same decline in ϵ. I then evaluate the aggregate impact of the shock in the new setting. Second, I undertake partial equilibrium analysis to help decompose the impact of the crisis into a bank channel and a collateral channel, holding general equilibrium effects constant. The first set of exercises gives a clearer picture of the aggregate impact of the mechanisms at play in the model, while the second set more clearly demonstrates the relative importance of each channel for firms across the age distribution.

2.6.1 Counterfactual Economies

In this set of exercises, I consider two counterfactual economies. In the first, I shut down the collateral channel by replacing the additional collateral from housing

$\xi_h(1 - \delta_h)q_h H_o$ with a constant $\bar{\xi}_h$ equal to the initial value of housing collateral in the baseline. That is, $\bar{\xi}_h = \xi_h(1 - \delta_h)q_{h,baseline}H_{o,baseline}$. This is a world where collateral constraints are the same as in the baseline, but do not tighten due to declining housing values as they do in the crisis regime. As a result, I denote this regime by "Bank Channel Only" in Table 2.6.

The second regime is one in which the spread between lending rates and deposit rates is constant, and bank net worth is a constant. Such an economy could be constructed by assuming an intermediation cost in the banker's problem to generate a spread between the deposit rate and the lending rate, and assuming that the incentive constraint is not binding either before or after the shock. The only profit would be generated by loans made from bank net worth, which carry the same interest rate as loans made from deposits. The lack of a binding constraint means that lending rates are equal to deposit rates plus the intermediation cost. In this case, housing collateral can deteriorate as house prices fall, but interest rates do not fluctuate. This is called the "Collateral Channel Only" regime.

The results for these economies are given in the third and fourth columns of Table 2.6. Given the same shock to ϵ, both regimes produce declines in employment that are muted in comparison to the crisis regime. Capital falls substantially in both regimes, but particularly in the regime with only the bank channel. The result is a large decline in output in both regimes, with the bank channel only regime giving a slightly larger drop in output. For the bank channel regime, this is reflective of higher labor and capital costs coming through an interest rate that is similar to that in the crisis regime. However, for the collateral channel regime, labor costs

fall. Still, labor demand is more constrained by the collateral constraint, as well as capital investment. The effect of the tighter constraint in this regime prevents firms from accumulating capital early in their life cycle, and it takes many periods for them to acquire capital equivalent to the baseline. Furthermore, owner-occupied housing declines by more in the collateral channel regime. This leads to a tighter constraint than is apparent from the smaller drop in house prices.

Debt falls by more in the collateral channel regime, although interest rates rise by more in the bank channel regime as in the original crisis regime. Aggregate TFP is surprisingly invariant to these shocks, and if anything rises slightly in the bank channel regime. This suggests small misallocation effects in steady state in response to the shocks considered in this paper.

It is important, in this model, that these two channels interact to produce the results in the crisis regime, as neither regime can match the aggregate declines in output, employment, or capital. This is in part due to the effect the bank channel has on mortgage rates that in turn creates a larger decline in housing values, as can be seen by the relatively large decline in housing values in the bank only regime (a decline of 24%) compared to the decline in the collateral only regime (15%). As bank balance sheets tighten, mortgage rates rise along with business rates. This leads to even lower house prices which reinforces the original drop in home values. Thus, this counterfactual reveals an additional important channel for banks to amplify the housing crisis through their impact on mortgage rates. This interacts with the collateral constraint by tightening it further, hitting young businesses even harder. Without the collateral channel, as in the regime with only the bank channel, aggre-

gate responses are milder than in the crisis regime because early life cycle capital accumulation is not affected in the same way. Thus, both channels serve to produce the aggregate outcomes in the crisis regime, but the amplification channel generated by the banking sector is key in obtaining these results.[19]

2.6.2 Partial Equilibrium Experiments

As discussed, shutting down a channel before computing the economy's reaction to a shock to ϵ importantly takes into account the general equilibrium effects of such a change. However, to examine how important the channel is for different firms across the age distribution in the crisis regime, one might want to consider partial equilibrium counterfactuals that take as given the general equilibrium effects. For example, it might be desirable to observe a counterfactual where house prices decline as in the crisis regime despite a lack of a bank channel. This would illustrate the impact of the *observed* house price decline in the crisis regime on firms through the collateral channel.[20]

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[19]Note that house prices fall by even more in the bank channel only regime. This is possible because there is no decline in collateral values. A decline in collateral values leads to a shift inward in credit demand, which puts downward pressure on interest rates. Without this shift, interest rates rise by even more than in the original crisis regime. This in turn puts further downward pressure on house prices through the mortgage rate.

[20]Holding general equilibrium effects constant will primarily require that I hold the wage constant at the baseline level. The three main objects determined in general equilibrium that are important for firm decisions are wages, interest rates, and housing collateral (house prices + owner-occupied housing stock). The experiments below generally involve allowing the latter two objects to move independently. As a result, wages will be artificially high and the series will be more severely
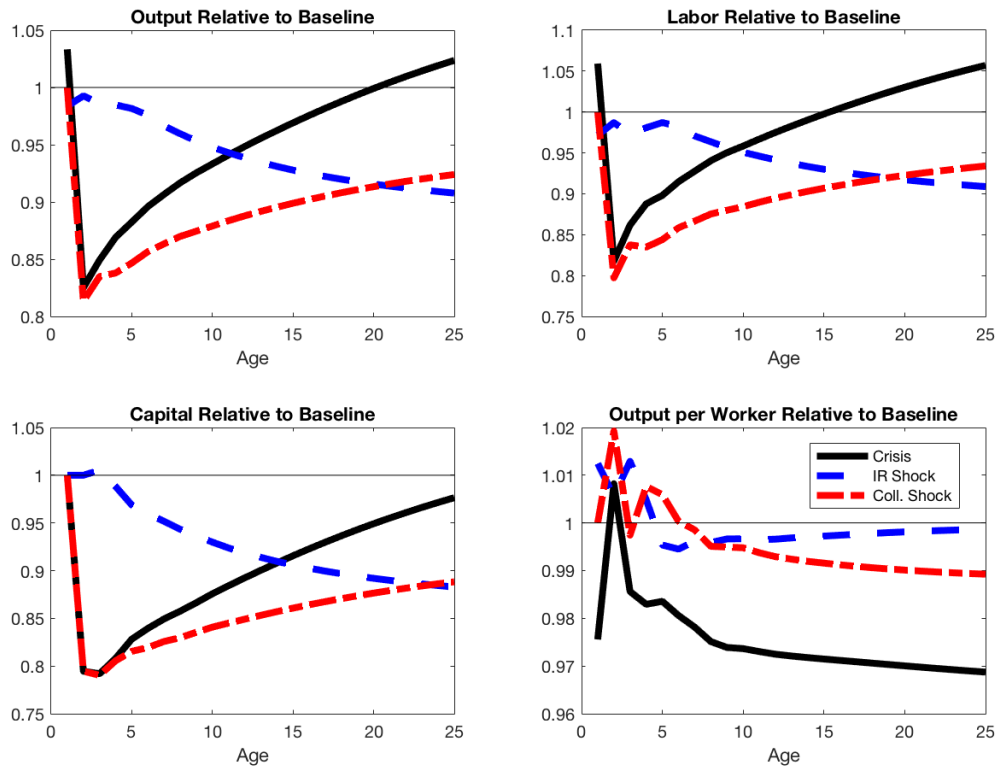
Figure 2.11: Decomposition of Channels: Age Profile of Firms

I consider two exercises. The first, denoted "IR Shock", is to consider the impact of an interest rate shock absent a housing collateral shock and general equilibrium effects observed in the crisis period. In this exercise, the interest rate is held constant at the level in the crisis (6.64%), but housing collateral is held constant at the baseline level. I then compute decision rules and the stationary distribution of firms given wages (set to the baseline level), interest rates, and housing collateral. This gives me the impact of interest rates on the firm distribution absent a collateral shock and general equilibrium effects. The second exercise is similar, in that I fix wages at the baseline level. However, in this exercise I assume house prices and

impacted than in the actual crisis regimes.

owner-occupied housing fall to their crisis level and interest rates remain at their pre-crisis level (5.33%). This exercise (the "Collateral Shock" regime) shows the impact of collateral values on the firm distribution absent an interest rate shock and general equilibrium effects.

For this exercise, it is more interesting to study the impact of the shock to the age cross-section of the firm distribution. In Figure 2.10, I again plot the crisis regime relative to the baseline. I then plot the interest rate shock and collateral shock regimes relative to the baseline as well. From these figures, it is clear that young firm performance is well-described by the collateral constraint shock, while the interest rate shock by itself does little to match the performance of young firms. As time goes on, however, the interest rate plays a larger role, as higher capital and labor costs lower the optimal scale of firms. This result is similar to the one found in Decker (2015), which finds that house price shocks can work through a housing collateral channel to produce a drop in entrepreneurship and entry like that seen in the Great Recession.

This result is particularly apparent for capital, as the collateral shock regime is similar to the crisis regime for roughly the first five years. In later periods, the interest rate drives output, employment, and capital downward when there is not an offsetting decline in wages. I interpret this result as consistent with the empirical results that collateral values are primary for young firms, but the bank channel explains little of the disproportionate impact of house prices on young firms. On the other hand, both collateral constraints and the bank channel matter for older firms, which is consistent with the data.

2.7 Conclusion

This paper presents new evidence on the impact of house prices on firm growth in the Great Recession. In particular, it highlights the role of a local bank channel in amplifying the house price shock. I find the effects working through the bank balance sheet channel are insignificant for young firms, although the total effect of house prices on young firms is large. On the other hand, I find the bank balance sheet mechanism is a significant and important channel for house prices to impact old and small firms. Old and large firms do not appear to be impacted by local house price shocks.

I then construct a model with heterogeneous producers where both banks and entrepreneurs are exposed to house prices. Bank exposure to housing via their endowment generates a contraction in credit supply in response to a collapse in house prices, which implies an increase in borrowing costs faced by firms. Furthermore, entrepreneurs are directly impacted by a deterioration in house prices through collateral values, since they are able to borrow against owner-occupied housing. In the model, young firms are particularly impacted by the housing collapse, just as in the data. I find that the collateral channel contributes greatly to this effect, as young firms are more reliant on collateral. However, older firms are more sensitive to the interest rate shock generated from the banking sector response to the house price decline. Furthermore, aggregate effects are greatly influenced by the banking channel, although the role of housing collateral is still significant. The banking sector not only directly impacts firms, but it amplifies the house price decline by driving up

interest rates on mortgages. All of this is accomplished without shocks to financial parameters or productivity, but by endogenous tightening in response to declines in housing values.

These results suggest that housing market conditions matter for both young and old/small firms, but the channels through which these firm types are affected differ. Quantitatively, the impact of the bank channel matters greatly for aggregate output in the immediate wake of a recession both through its direct effect on businesses and its amplification of the decline in house prices. The impact on young firms through the decline in collateral values is important because it reduces output and capital accumulation in the early stages of the business. In future work, I plan to investigate the implications of the disproportionate impact on young businesses for the recovery from a recession induced by a collapse in housing values.

Chapter 3: Financial Markets, Productivity Dispersion, and Misallocation

3.1 Introduction

Did variation in financial conditions faced by businesses matter for micro-level and aggregate outcomes in the most recent financial crisis? This paper analyzes the potential for utilizing patterns in labor productivity, and in particular dispersion in labor productivity, to infer the importance of variation in financial conditions. Furthermore, I explore the distinction between the impact of heterogeneous financial shocks on dispersion *across* geographies and *within* geographies. For example, a financial shock that falls unevenly across locations could cause misallocation between firms across those locations, but it could also cause misallocation within each location, amplifying or mitigating the impact on dispersion across geographies. I build on the framework of Hsieh and Klenow (2009) by incorporating a standard financial friction and owned capital, I decompose dispersion (and therefore inferred misallocation) into within and between components. I then further show the within-location contribution can be decomposed into terms related to the behavior of constrained and unconstrained firms.

The paper is motivated by apparent differences in financial conditions faced by firms. Specifically, I focus on geographic access to banks and banking relationships. That geography is an important determinant in credit conditions faced by the firms is suggested by the close proximity of most small businesses to their lenders (see Peterson and Rajan (2002) and Agarwal and Hauswald (2010), e.g.). Likewise, the potential for lending relationships overcoming agency problems to ease credit conditions has been established (see Boot and Thakor (1994), e.g.). More recently, empirical work such as Greenstone et al. (2014) and Chodorow-Reich (2014) has explored the impact of geographic segmentation and financial relationships, respectively, finding impacts of lender health on credit conditions.

In the previous chapter, I showed the relevance of local banking conditions, characterized by FDIC call report data on bank balance sheets, to identify the states that are more precariously positioned prior to the onset of the Great Recession. I argued this identifies a credit supply effect that potentially amplifies an unexpected decline in housing prices. However, my empirical work was silent as to the exact nature of the financial shock, which could be either an interest rate shock (as in Gertler and Kiyotaki (2015)), a collateral shock (as in Khan and Thomas (2013)), or some other type of financial shock. This paper takes seriously the implications of geographic segmentation by exploring the implications of an islands model. Additionally, I discuss the effects of several shocks considered in the literature, noting how they differ in terms of implications for productivity measures.

I focus on both employment and measures of labor productivity, and I further I distinguish between effects of heterogeneous shocks on outcomes *across* geographies

as opposed to those *within* geographies. I first show that heterogeneous shocks to financial conditions can lead to increased dispersion of outcomes across geographies, while the reaction of dispersion within a locality to a financial shock depends on the type of shock. Interest rate shocks can potentially *decrease* dispersion in both productivity and employment growth rates, while collateral shocks increase dispersion. These changes in dispersion, in this framework, are indicative of changes in misallocation, as in Hsieh and Klenow (2009). This implies that the nature of financial shock (i.e. whether it impacts the price or extension of credit) is crucial for determining the allocative effect of a crisis.

Key to my analysis is a variance decomposition of labor productivity dispersion into within-geography and between-geography impacts. I undertake some simple comparative statics to illustrate first-order impacts of various financial shocks, abstracting from long-run distributional impacts. I show that between-geography dispersion can easily summarized as a function of the difference in geography means to the overall mean. I then show that within-geography labor productivity dispersion has multiple components, but crucially relies on the dispersion of constrained firms. In these exercises, I show that interest rate shocks and collateral constraint shocks have qualitatively different effects on within-isand labor productivity dispersion.

I then construct a general equilibrium version of the model with two key features of financial markets: geographic segmentation with heterogeneous financial intermediation costs and collateral constraints that depend on the age of a firm's current relationship with a bank. These features allow me to investigate the role of various financial shocks, both across and within localities. Utilizing the variance

decomposition I derived, my results show little role for between-island dispersion relative to within-island dispersion. However, I consider scenarios in which between island dispersion plays a larger role. Furthermore, I discuss the impact of each shock on within-island dispersion and overall dispersion. I find that short run effects are in line with my simple analytics, but long-run distribution changes may mute the effects of the initial impact.

3.2   Related Literature

This paper relates closely with the recent literature investigating the importance of heterogeneity in financial conditions faced by firms. While notions of geographic segmentation in financial markets had been incorporated into macro models (see Williamson (1989) and Morgan et al. (2004), e.g.) and the finance literature had investigated the role of relationships in determining firm outcomes (see Peterson and Rajan (1994) and Berger and Udell (1995), e.g.), the onset of the financial crisis in 2008 and subsequent recession has led to a renewed interest in these aspects in the macro-finance literature. Chodorow-Reich (2014) uses syndicated loan data to document the importance of pre-crisis financial relationships in determining outcomes, suggesting as much as one third of the drop in employment can be linked to relationship frictions.[1] Boualam (2015) likewise presents a search and matching model where the deterioration in relationship frictions can be important for determining aggregate outcomes.

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[1]Additionally, the DSGE model employed in the appendix of the paper is a simple islands model, similar in spirit to the model I consider here.

Recent empirical papers have begun to explore the importance of geographic segmentation of financial markets over the past few decades in the US. Greenstone et al. (2014) use loan origination data for large banks to develop a "Bartik" style credit supply shock based on variation in county footprints of these banks. They downplay the importance of such shocks over the recession, suggesting limited impacts on real variables. Davis and Haltiwanger (2017) consider both house prices' and similar large bank credit supply shocks' effect on young business outcomes. While they find significant effects of a similar Bartik shock, they emphasize a larger effect of house prices on local market outcomes, in particular in the Great Recession. My previous chapter contributes to this literature by exploring the role of the local banking sector, finding substantial impacts of the interaction between local house prices and local bank balance sheets.

Within the broad theoretical literature on financial frictions, my paper also sits within a growing literature of models of financial frictions with heterogeneous firms. Recent papers that investigate a "credit crunch" include Khan and Thomas (2013), Midrigan and Xu (2014), and Buera and Moll (2015). My paper is most similar to Khan and Thomas in that I consider a discrete time setup with decreasing returns to scale (in revenue production). I also allow for investment decisions to be made prior to the realization of next period shocks. However, I do not consider aggregate risk in my model, and the model is entrepreneurial in that each firm is owned by a single proprietor. Additionally, recent work has considered various credit supply shocks that generate higher cost of borrowing (see Gertler and Karadi (2011), Gertler and Kiyotaki (2015)). I utilize simple interest rate spread shocks

in this model, similar to Ajello (2016). Additionally, the assumption of a isoelastic demand and constant returns to scale, and the implications these assumptions have for misallocation, follow Hsieh and Klenow (2009).

My analysis shares many symmetries with Gopinath et al. (2016), who also utilize a framework similar to Hsieh and Klenow (2009), using the setup to explore the allocative implications of interest rates in the context of European financial liberalization. Likewise, I investigate the role of different financial shocks and their impact on aggregate and distributional outcomes, and use the data to suggest which shocks best fit. I focus on both short run and long-run outcomes in my framework, but my ultimate goal is to draw implications about labor productivity over the business cycle in the context of the United States. Their focus is to explain long run trends in marginal revenue products of capital in the context of European financial market integration. Still, their point that lower interest rates can increase misallocation is a mirror image to one of the interest rate shocks I consider, and the inverse relationship between interest rates and misallocation is a common thread between these papers.

To provide an accounting framework that will illustrate the variation in outcomes based on the type of shock, I write down a simple model (consisting primarily of the firm's problem in my general equilibrium framework) to fix ideas about what to expect in the next section.

3.3 Producer framework and Analytics

In this section, I use the static firm's problem from a model similar to Hsieh and Klenow (2009) as an accounting framework for describing the effect of various credit supply shocks. This problem will be incorporated into a general equilibrium framework later in the paper, but I want to focus on the static portion of the problem here to fix ideas about how employment and labor productivity at the firm level should respond to various shocks. Importantly, this model will abstract from various sources of dispersion and variation in labor productivity. Frictions and/or distortions, adjustment costs, overhead labor, dispersion in factor prices, and non-CES demand structure could result in variation in productivity and productivity growth across firms. However, the model presented here is a simplified view through which I can investigate the partial equilibrium impact of various shocks on the change in productivity, as well as labor.

Consider a final good produced by a simple CES aggregator. Intermediate goods are produced by a continuum of firms with constant returns in physical inputs. Each intermediate firm enters into the period with capital holdings k. Focusing on the static problem, the primary friction is that the firm must pay labor up front using a working capital constraint $(1 + r_n)wh \leq \xi(a)(1 - \delta)k$. That is, firms can borrow up to some fraction ξ_n of their capital k (depreciated by δ) to pay workers at wages w for hours h. The fraction ξ_n is a function of relationship age a, and r_n is the lending rate on island n. The resulting static profit maximization problem for the intermediate firm, taking demand structure, physical capital, and existing,

is given by:

$$\max_{h} Y^{1-\rho} z^{\rho} k^{\rho\alpha} h^{\rho(1-\alpha)} - (1+r_n)wh \tag{3.1}$$

s.t.

$$(1+r_n)wh \leq \xi_n(a)(1-\delta)k \tag{3.2}$$

3.3.1 Labor Outcomes

The resulting first order conditions give the optimal labor allocation:

$$h_{opt} = \left(\frac{\rho(1-\alpha)Y^{1-\rho} z^{\rho} k^{\rho\alpha}}{(1+r_n)w} \right)^{1/(1-\rho(1-\alpha))} \tag{3.3}$$

From this one can see changes in employment depend on a variety of factors, including general demand effects (Y), wages (w), productivity (Z), and capital holdings (k). Importantly, the optimal allocation also depends on the interest rate, which is the result of the working capital friction. One source of differences in employment outcomes across locations n could be differences in financial conditions, even for unconstrained firms.

For constrained firms, there is the following expression for employment:

$$h_{con} = \frac{\xi_n(a)(1-\delta)k}{w(1+r_n)} \tag{3.4}$$

In addition to the effect of interest rates that is similar to the effect for unconstrained firms, it is clear that a negative shock to collateral constraints $\xi_n(a)$ negatively impacts employment. Since ξ varies with relationship age, banking relationships are important in determining labor outcomes for the firm. Furthermore, capital holdings

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are also important, and in general firms will be able to "outgrow" their collateral constraints by accumulating capital. Importantly, productivity and demand do not enter into the equation above, since the constraint, when tight, is an arbitrary impediment to accumulating labor, and therefore inefficient.

Note the point where $h_{opt} = h_{con}$ defines the boundary between constrained and unconstrained firms:

$$k^*(z, \xi_n(a), r_n, w, Y) = \tag{3.5}$$

$$\left(\left(\rho(1-\alpha) Y^{1-\rho} z^\rho \right)^{\frac{1}{(1-\rho(1-\alpha))}} \left((1+r_n)w \right)^{1 - \frac{1}{(1-\rho(1-\alpha))}} \left(\frac{1}{\xi_n(a)(1-\delta)} \right) \right)^{1 - \frac{\rho\alpha}{(1-\rho(1-\alpha))}}$$

3.3.2 Labor Productivity outcomes

Rearranging equation 3 above, I can characterize labor productivity in terms of output per unit of labor (OPL) for each optimizing firm:

$$OPL_{opt} = \frac{Y^{1-\rho} z^\rho k^{\rho\alpha} h^{\rho(1-\alpha)}}{h} = \frac{(1+r_n)w}{\rho(1-\alpha)} \tag{3.6}$$

Labor productivity is constant across unconstrained firms in location n, and the only difference across islands among unconstrained firms results from the difference in interest rate r_n. This stark result is partly derived from the CES structure of demand combined with Cobb-Douglas production. In reality, variation in factor prices (w) or non-isoelastic demand could lead to dispersion in productivity without financial constraints. Given that the nature of the theoretical experiments I run are financial, I focus on this type of production and demand structure to highlight the potential effect of financial conditions.

For constrained firms, I can simply plug equation 4 into the production function and rearrange to obtain:

$$OPL_{con} = \frac{Y^{1-\rho}z^{\rho}}{k^{1-\rho}} \left(\frac{(1+r_n)w}{\xi_n(a)(1-\delta)} \right)^{1-\rho(1-\alpha)} \tag{3.7}$$

Again, productivity is tied to financial conditions through the interest rate and the collateral constraint. Productivity will vary idiosyncratically across constrained firms, and labor productivity is now a function of TFP z, total output Y, and firm capital k. Thus, all dispersion in labor productivity is driven by differences in interest rates across locations and the effects of the collateral constraint, since OPL would be constant across firms if all locations faced the same interest rate and did not face collateral constraints.

3.3.3 Partial Equilibrium Effects of Financial Shocks

Consider changes to the primary financial variables in the model: r_n, ξ_n, and a. That is, there can be a pure credit supply shock, which effects borrowing rates r_n despite no initial change in underlying deposit rates, an "imposed credit demand" shock when the collateral constraint tightens, or a deterioration in banking relationship ages a (which will occur with some probability in the full model). As will become clear, each of these shocks will imply similar effects in terms of employment, but different effects in terms of labor productivity.

Consider interest rate and collateral constraint shocks to $ln(h)$ and $ln(OPL)$, which translate to percentage changes in hours and OPL. For unconstrained firms,

the response of $ln(h)$ to an interest rate shock is given by:

$$\frac{dln(h_{opt})}{dr_n} = -\frac{1}{1-\alpha_2}\frac{1}{1+r_n} \qquad (3.8)$$

and for constrained firms:

$$\frac{dln(h_{con})}{dr_n} = -\frac{1}{1+r_n} \qquad (3.9)$$

That is for both constrained and unconstrained producers, one would expect hours to decline with an increase in the interest rate. On the other hand, in collateral constraints are shocked:

$$\frac{dln(h_{opt})}{d\xi_n} = 0 \qquad (3.10)$$

for unconstrained firms, and for constrained firms:

$$\frac{dln(h_{con})}{d\xi_n} = \frac{1}{\xi_n(a)} \qquad (3.11)$$

Thus hours for constrained firms only increase with a loosening of the collateral constraint. The analogs for labor productivity are given as follows.

Interest Rate Shock:

$$\frac{dln(OPL_{opt})}{dr_n} = \frac{1}{1+r_n} \qquad (3.12)$$

$$\frac{dln(OPL_{con})}{dr_n} = \frac{1-\alpha_2}{1+r_n} \qquad (3.13)$$

Collateral Constraint Shock:

$$\frac{dln(OPL_{opt})}{d\xi_n} = 0 \qquad (3.14)$$

$$\frac{dln(OPL_{con})}{d\xi_n} = -\frac{1-\alpha_2}{\xi_n(a)} \qquad (3.15)$$

Thus, $ln(OPL)$ rises with an increase in interest rates, and it also rises with a decline in collateral requirements, but only for constrained firms.

From a macro perspective, if a large financial shock hits an economy, and its impact is heterogeneous across islands, then there is the potential to generate larger amplification of the shock as productivity can become more dispersed. Thus, allowing a shock such as the financial crisis of 2008 and 2009 to differentially affect various localities could help explain some of the amplification of the initial impulse and the depth of the resulting recession. In the next section, I will discuss the implications for dispersion more explicitly.

3.4   Financial Shocks and Productivity Dispersion

Given the above characterization of firm choices, and assuming the economy is in an equilibrium in which the constraint occasionally binds (that is some firms are constrained while others are unconstrained), I will now construct a measure of variance in labor productivity in the economy (σ_{LOPL}) that is a function of measures of dispersion in log labor productivity *within* islands (σ^n_{LOPL}) and measures of dispersion *across* islands. As will become clear, heterogeneous financial shocks have the potential to create dispersion across islands. However is not as clear whether they create more *within* island dispersion. That is, the impact of financial shocks on dispersion and misallocation of inputs depends on the type of financial shocks.[2]

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[2]Khan and Thomas (2013) find that financial shocks embodied in a "credit crunch", or tightening collateral constraint, increase misallocation. However, Gopinath et al. (2015) note that a decline in interest rates, a type of relaxation in financial conditions, can lead to increased misallo-

I begin overall variance in log labor productivity σ_{LOPL}^2, which can be decomposed as follows:

$$\sigma_{LOPL}^2 = \underbrace{\sum_{n=1}^{N} m_n \left(\sigma_{LOPL}^n\right)^2}_{\text{within-island dispersion}} + \underbrace{\sum_{n=1}^{N} m_n \left(\overline{LOPL}_n - \overline{LOPL}\right)^2}_{\text{between-island dispersion}} \qquad (3.16)$$

Defining m_n as the mass of firms on island n (assumed to be fixed), $\overline{LOPL}_n$ as the average log labor productivity dispersion on island n, and $\overline{LOPL}$ as the overall average log labor productivity dispersion, it is apparent that total dispersion is composed of two terms. First is the weighted average of log labor productivity dispersion on each island. In other words, this is the contribution of "within-island dispersion" to overall productivity dispersion. Second, there is the weighted sum of squared differences between mean labor productivity on each island and the overall mean log labor productivity. This represents the contribution of cross-island average differences to total dispersion, which I call "between-island dispersion." The remainder of this section will focus on each of the two components in turn.

First, I show that the direction of the impact of a financial shock on productivity dispersion within islands can be decomposed into the effect on dispersion of constrained firms $(\sigma_{LOPL,con}^n)$, the relative mean of constrained log labor productivity$(\overline{LOPL}_{con,n} - \overline{LOPL}_n)$, the relative mean of unconstrained log labor productivity and $(\overline{LOPL}_{opt,n} - \overline{LOPL}_n))$, and the measure of constrained firms (μ^n). I will show that each of these effects increase within island dispersion in response to a collateral constraint shock, but decrease within island dispersion in response to an interest rate shock. I then turn to investigate the impact of interest

cation.

rate and productivity shocks on "between-island" dispersion, showing that the effect of both shocks is to unambiguously increase cross-island dispersion. Finally, I will address the extensive margin. Here, I reach the limits of these simple analytics. While I will be able to characterize the *initial* reaction of productivity dispersion to financial shocks, the endogenous response of the distribution will imply dynamics that must be explicitly modeled in a quantitative framework.

3.4.1 Within-Island Dispersion

I first begin by exploring within island dispersion in depth. To begin, I consider a further decomposition of $(\sigma_{LOPL}^n)^2$:[3]

$$(\sigma_{LOPL}^n)^2 = \underbrace{\mu_n \left(\sigma_{LOPL,con}^n\right)^2}_{\text{constrained dispersion}} \tag{3.17}$$

$$+ \underbrace{\mu_n \left(\overline{LOPL}_{con,n} - \overline{LOPL}_n\right)^2 + (1 - \mu_n) \left(\overline{LOPL}_{opt,n} - \overline{LOPL}_n\right)^2}_{\text{relative mean contribution}}$$

I will first consider what occurs given a fixed distribution among constrained and unconstrained firms. I then turn to the extensive margin before summarizing within-island impacts of financial shocks.

3.4.1.1 Constrained Firm Dispersion

The first term is the contribution of within island dispersion of constrained firms. Note that there is no dispersion of labor productivity among unconstrained

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[3]Note that since log labor productivity of unconstrained firms $ln(OPL_{opt}) = ln(1+r_n) + ln(w) - ln(\rho(1-\alpha))$, within island dispersion of unconstrained firms $\sigma_{opt,n}^n = 0$, and so is not included in this equation.

firms, so only the mean of unconstrained firms relative to the island mean contributes to dispersion, which I collect with relative mean of constrained firms to the island mean as the "relative mean contribution." Formally defining each of the components:

$$\mu_n = \int_z \int_a \int_{k=0}^{k^*(z,\xi_n(a),r_n,w,Y)} \iota(z,k,a) \, dk \, da \, dz \tag{3.18}$$

where $\iota(z,k,a)$ is the mass of firms (z,k,a), and k^* is as defined in equation (5).[4]

Dispersion in constrained firm labor productivity is given by:

$$\left(\sigma_{LOPL,con}^n\right)^2 = \rho^2 \sigma_{n,z}^2 + (1-\rho)^2 \sigma_{n,k}^2 + (1-\rho(1-\alpha))^2 \sigma_{n,\xi}^2 \tag{3.19}$$

$$-2\rho(1-\rho)\sigma_{n,z,k} - 2\rho(1-\rho(1-\alpha))\sigma_{n,z,\xi} + 2(1-\rho)(1-\rho(1-\alpha))\sigma_{n,k,\xi}$$

Where $\sigma_{n,z}^2$ is the variance of log idiosyncratic productivity on island n, $\sigma_{n,k}^2$ is the variance of log capital on island n, and $\sigma_{n,\xi}^2$ is the variance of $ln(\xi_n(a))$. Additionally, cross terms $\sigma_{n,u,v}$ denote the covariances between variables u and v. Crucially, note that the interest rate r_n does not enter into dispersion of log labor productivity for constrained firms. This means that the impact of interest rates on productivity dispersion will solely impact overall dispersion through changes in relative means, cross-island dispersion, and distributional shifts. On the other hand, the effect of a tightening in the ξ function on constrained dispersion will depend on several factors. First, it will depend on whether the tightening is uniform

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[4]Note here that the distribution is assumed to be static, but in reality it will be an endogenous object that responds to changes in financial conditions. The rest of what follows can be considered analysis of the impact, or initial period after a shock. A quantitative model is necessary to explore either the long-run implications or transition paths past the first period after a shock. I explore such a model in my quantitative section.

across age groups. If the constraint tightens by the same percentage for each age $(\xi'_n(a) \propto \xi_n(a))$, and if the mass of constrained firms remains constant, there will be no change in log productivity dispersion among constrained firms. However, if the shock is not uniform (some relationship ages a are impacted by larger percentage declines in $\xi_n(a)$), or if I account for the fact that new firms will become constrained due to the tightening, then dispersion among constrained firms will change.

3.4.1.2 Relative Mean Contribution

Since optimal OPL is equalized across firms:

$$\overline{LOPL}_{opt,n} = ln(1 + r_n) + ln(w) + ln(\rho(1 - \alpha)) \tag{3.20}$$

On the other hand, the mean of constrained firms will depend on the distribution.

$$\overline{LOPL}_{con,n} = (1 - \rho)ln(Y) + (1 - \rho(1 - \alpha))(ln(1 + r_n) + ln(w) - ln(1 - \delta)) \tag{3.21}$$

$$+\frac{1}{\mu_n}\left[\int_z \int_a \int_{k=0}^{k*} \iota(z, k, a) \left[\rho ln(z) - (1 - \rho)ln(k) - (1 - \rho(1 - \alpha))ln(\xi_n(a))\right] dk \, da \, dz\right]$$

Finally, there is the term $\overline{LOPL}_n = \mu_n \overline{LOPL}_{con,n} + (1 - \mu_n)\overline{LOPL}_{opt,n}$. Holding the distribution constant, I can now evaluate the impact of a change in the parameters of interest.

$$\frac{d\overline{LOPL}_{opt,n}}{dr_n} = \frac{1}{1 + r_n} \tag{3.22}$$

$$\frac{d\overline{LOPL}_{con,n}}{dr_n} = \frac{1 - \rho(1 - \alpha)}{1 + r_n} + \frac{1 - \rho}{Y}\frac{dY}{dr_n} \tag{3.23}$$

Comparing the first terms in(22) and (23):

$$\frac{1 - \rho(1 - \alpha)}{1 + r_n} < \frac{1}{1 + r_n} \tag{3.24}$$

Additionally, the second term in (23) is negative so long as $dY/dr_n < 0$. This implies:

$$\frac{d\overline{LOPL}_{opt,n}}{dr_n} \geq \frac{d\overline{LOPL}_n}{dr_n} \geq \frac{d\overline{LOPL}_{con,n}}{dr_n} \tag{3.25}$$

This in turn means that the mean of unconstrained firms reacts more to a change in interest rate than the mean of constrained firms. If interest rates are rising, this means $d\overline{LOPL}_{opt,n}/dr_n$ and $d\overline{LOPL}_{con,n}/dr_n$ (and thus $d\overline{LOPL}_n/dr_n$), but since the *relative* mean of constrained firms is changing less than unconstrained firms, the change in $\overline{LOPL}_{con,n} - \overline{LOPL}_n$ should be negative, while the change in $\overline{LOPL}_{opt,n} - \overline{LOPL}_n$ is positive. Since the relative mean of constrained is above the island mean, this means the relative mean of unconstrained firms is declining. On the other hand, the mean of unconstrained firms is rising relative to the island mean, narrowing the gap since it is less than or equal to the island mean. Both forces serve to reduce dispersion, absent a change in μ_n, which I consider in the next section.

In the case of a tightening in collateral constraints, the picture is somewhat more complicated. Regardless of distributional changes, however, the following is true:

$$\frac{d\overline{LOPL}_{opt,n}}{d\xi_n(a)} = 0 \tag{3.26}$$

To evaluate the impact on constrained firms, assume the collateral constraint function takes the form $\xi_n(a) = \kappa_n \xi(a)$. If I hold the distribution of constrained firms constant, then the change in mean constrained firms in response to a shift in κ_n is given by:

$$\frac{d\overline{LOPL}_{con,n}}{d\kappa_n} = -\frac{1 - \rho(1 - \alpha)}{\kappa_n} + \frac{1 - \rho}{Y} \frac{dY}{d\kappa_n} \tag{3.27}$$

Clearly, this implies that the relative mean of constrained firms will react more to a tightening in the collateral constraint, which means dispersion will rise as $\overline{LOPL}_{con,n} - \overline{LOPL}_n$ rises and $\overline{LOPL}_{opt,n} - \overline{LOPL}_n$ falls. While the picture is more complicated if there is not a proportional decline across a, so long as the mean constraint falls, this result will hold.

3.4.1.3 Extensive Margin: μ^n

From the simple analytics above, I can evaluate the impact of financial shocks on the marginally constrained firm (the firm where the constraint is just binding) to infer the impact on the extensive margin. First, note that the marginally constrained firm is the firm where optimal labor productivity is exactly equal to constrained productivity:

$$OPL_{opt} = \frac{(1+r_n)w}{\rho(1-\alpha)} = \frac{Y^{1-\rho}z^\rho}{k^{1-\rho}} \left(\frac{(1+r_n)w}{\xi_n(a)(1-\delta)} \right)^{1-\rho(1-\alpha)} = OPL_{con} \qquad (3.28)$$

In order to evaluate how this firm responds to the shock, I utilize the responses from section 3. For an interest rates shock, it is clear that the optimal value is more responsive.

$$\frac{dln(OPL_{con})}{dr_n} = \frac{1-\alpha_2}{1+r_n} + \frac{1-\rho}{Y}\frac{dY}{dr_n} < \frac{1}{1+r_n} = \frac{dln(OPL_{opt})}{dr_n} \qquad (3.29)$$

Since the optimal values is declining by more than the constrained value (from an initial point where they were equalized), the firm becomes unconstrained (the constraint is no longer marginally binding).

However, the response to a collateral constraint shock reverses the order:

$$\left| \frac{dln(OPL_{con})}{d\xi_n} \right| = \left| -\frac{1 - \alpha_2}{\xi_n(a)} \right| > 0 = \left| \frac{dln(OPL_{opt})}{d\xi_n} \right| \qquad (3.30)$$

Here, constrained $LOPL$ adjusts by more than unconstrained LOPL, implying that the firm now becomes unconstrained.

Extrapolating these movements to the broader set of firms, I argue that a mass of firms who were previously constrained will become unconstrained in response to an interest rate shock, while a mass of unconstrained firms will become constrained in response to a collateral constraint shock.

What does this extensive margin imply for the other components of within-island dispersion? A further decomposition separating $(\sigma^n_{LOPL,con})^2$ could be contrived, breaking the term into "previously" constrained" and "newly constrained." For now, I will note that the result of this decomposition would be ambiguous, and leave the derivation to future work.

3.4.1.4 Within-Island Summary

Pulling together the discussion above, I now summarize the impacts of an interest rate shock an a collateral constraint shock. I begin with an interest rate shock. For each component of within-island dispersion, I note the reaction of each term to an increase in the interest rate r_n. I note by $*$ each case where distributional aspects will potentially counteract this effect.

Response of within-island log labor dispersion to an increase in r_n:

$$(\sigma_{LOPL}^n)^2 = \underbrace{\mu_n}_{\Delta \leq 0} \underbrace{(\sigma_{LOPL,con}^n)^2}_{(\Delta < 0)^*} + \underbrace{\mu_n}_{\Delta \leq 0} \underbrace{(\overline{LOPL}_{con,n} - \overline{LOPL}_n)^2}_{\Delta < 0} \qquad (3.31)$$

$$+ \underbrace{(1 - \mu_n)}_{\Delta > 0} \underbrace{(\overline{LOPL}_{opt,n} - \overline{LOPL}_n)^2}_{\Delta < 0}$$

Here, the effect of each component generally work to increase dispersion (absent distributional changes denoted by $*$), except the increase in the share of unconstrained firms, making the effect of the last term dependent on the change in the relative mean of unconstrained firms. However, the total effect of the relative means (the second and third terms) should work to decrease dispersion even if the third term contributes more to dispersion on net, at least in the short run.[5]

Response of within-island log labor dispersion to a uniform decline in $\xi_n(a)$:

$$(\sigma_{LOPL}^n)^2 = \underbrace{\mu_n}_{\Delta \geq 0} \underbrace{(\sigma_{LOPL,con}^n)^2}_{(\Delta > 0)^*} + \underbrace{\mu_n}_{\Delta \geq 0} \underbrace{(\overline{LOPL}_{con,n} - \overline{LOPL}_n)^2}_{\Delta > 0} \qquad (3.32)$$

$$+ \underbrace{(1 - \mu_n)}_{\Delta < 0} \underbrace{(\overline{LOPL}_{opt,n} - \overline{LOPL}_n)^2}_{\Delta > 0}$$

The response of dispersion is the mirror image of the response to interest rate shocks. Again, there is some abstraction from distributional aspects here, but the general picture is one of increased dispersion in response to a tightening in collateral constraints.

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[5]However, as μ_n goes to 1, the relative means disappear. This implies within island dispersion is solely driven by constrained dispersion, and distribution changes matter even more, especially in the long run.

3.4.2 Cross-Island Dispersion

Given responses of within-island dispersion, I can now evaluate the impact of shocks on between-island dispersion. This term relies solely on relative means of each island to the overall mean. As seen before, within-island means are a function of constrained and unconstrained means. Constrained means are dependent, in part on the distribution of firms. I consider two cases to evaluate potential impacts of financial shocks on cross-island dispersion. First, I consider interest rate dispersion when there are no constrained firms (a case where there are no collateral constraints). Second, I consider collateral constraint shocks when the constraint binds for all firms. These illustrative examples help guide expectations for the results of a calibrated model.

3.4.2.1 Cross-island Dispersion and Interest Rates

Suppose the constraint $\xi_n(a)$ is not binding for any firm on any island at any age. Then, I can summarize $\overline{LOPL}_n = ln(1+r_n) + ln(w) + ln(\rho(1-\alpha))$. Then, the overall mean of log labor productivity can be written as:

$$\overline{LOPL} = ln(w) + ln(\rho(1-\alpha)) + \sum_{n=1}^{N} m_n ln(1+r_n) \qquad (3.33)$$

I can then write the relative mean of island log labor productivity to overall log labor productivity as the difference between the island log gross interest rates and average log gross interest rates across islands ($\bar{r}$):

$$(\overline{LOPL}_n - \overline{LOPL}) = ln(1+r_n) - \sum_{i=1}^{N} m_i ln(1+r_i) = ln(1+r_n) - \bar{r} \qquad (3.34)$$

Re-writing the second term of (16):

$$\sum_{n=1}^{N} m_n(\overline{LOPL}_n - \overline{LOPL}) = \sum_{n=1}^{N} m_n(ln(1+r_n) - \bar{r})^2 \qquad (3.35)$$

Under this set of assumptions, there is no within island dispersion in log labor productivity. Thus, the above equation defines both dispersion in log gross interest rates and log labor productivity:

$$\sigma_{LOPL}^2 = \sigma_r^2 = \sum_{n=1}^{N} m_n(ln(1+r_n) - \bar{r})^2 \qquad (3.36)$$

3.4.2.2   Cross-Island Dispersion and Collateral Constraints

Noting again that island means are the weighted means of constrained and unconstrained firms, and that unconstrained firm labor productivity is unaffected by collateral constraints, I can focus on the mean of constrained firms in response to a shift in collateral constraints. If one supposes a proportional shift as before, from (3.27) it is clear the change in log island productivity, so long as the distribution is fixed, will depend on the extent to which κ_n changes. If a shock across islands differs in terms of its impact on κ_n for each n, then the relative means will be impacted through the first term in equation (3.27).

However, I will note that this only impact constrained firms, muting the effect this may have on changes in island mean log labor productivity. On the other hand, as the distribution changes, this could cause either an increase or decrease in the mean. Thus, it is difficult to discern the extent of the impact of the shock on overall dispersion, as it will depend on the dispersion of the shock and the effect on the distribution.

To get a better sense of both the impact of shocks on the distribution, which could counteract some of the effects highlighted here, and in order to quantify the impacts of financial shocks on dispersion, and the individual components of dispersion, I will turn to a quantitative model

3.5   Quantitative Model

I now turn to the full version of the model to explore the predictions from earlier sections in a general equilibrium setting. In particular, I quantify the contributions of the various components of productivity dispersion discussed above. I consider the impact on aggregate quantities and total factor productivity in both the short run and the long run.

The model consists of three types of agents: a representative household, a continuum of entrepreneurs/producers who are heterogeneous in productivity, portfolio holdings, banking relationship age, and location, and financial intermediaries who take deposits from the household and lend to entrepreneurs. Entrepreneur borrowing is impeded by two financial frictions: a collateral requirement (which varies according to banking relationship age) and geographic financial market segmentation. Entrepreneurs and banks are divided among banking islands. Banks and entrepreneurs can only engage in lending arrangements if they are located on the same island.

Additionally, there are limited life cycle dynamics in that entrepreneurs are born exogenously and are subject to an exogenous death shock, which are standard.

The household's problem is also standard, and bank decisions will be fairly straight-forward. I describe household and entrepreneur problems, then I describe life cycle dynamics of firms, and finally I discuss the financial intermediary's problem.

3.5.1 Household Problem

The household maximizes utility over consumption c and leisure l, provides labor $H = 1 - l$ to producers at wage w, and saves s at deposit rate r in a single financial market (banks compete in a single deposit market). I will not delve too deeply into the decisions of the household, as it is standard, but for completeness, they are given by:

$$\max_{\{c_t, H_t\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta U(c_t, 1 - H_t) \tag{3.37}$$

s.t.

$$c_t + q_{t+1} s_{t+1} = s_t + w_t H_t + \pi_t \tag{3.38}$$

Bank profits π_t are potentially positive, but in the simple setup I discuss in this document, profits will be zero. Importantly, first order conditions imply that in steady state:

$$q = \beta \tag{3.39}$$

This, in turn implies an interest rate on savings at:

$$r = \frac{1}{\beta} - 1 \tag{3.40}$$

For the purposes of calibration, I will assume $U(.,.)$ takes the form:

$$U(c_t, 1 - H_t) = log(c_t) + \phi(1 - H_t) \tag{3.41}$$

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This will allow me to write wage as the product of consumption and the preference parameter on leisure:

$$w_t = \phi c_t \tag{3.42}$$

3.5.2 Entrepreneurs

I assume a continuum of measure 1 entrepreneurs exist, each producing a variety i of the intermediate good. Without loss of generality, I assume there are N discrete islands, and that the continuum of entrepreneurs is divided up among these islands such that an equal number is on each island.

With the addition of idiosyncratic risk, entrepreneurs maximize over future expected utility.

$$V_n(z_i, k, b, a) = \max_{c,\ell,k',h} ln(c) + \beta \zeta E\left[V_n(z_i', k', b', a')\right] \tag{3.43}$$

The producer maximizes over consumption, labor, loans, and future capital subject to the following budget constraint:

$$c + k' + q(b')b' = p_i z_i k^\alpha h^{1-\alpha} + (1-\delta)k + b - (1+r_n)\ell \tag{3.44}$$

Where the first term on the right hand size is a Cobb-Douglas production function with constant returns multiplied by a product specific price. Capital evolves in the typical fashion: $k' = (1-\delta)k + i$. Intertemporal debt b' is chosen at the end of the period, and ℓ is the amount of working capital loans taken out of the producer. The amount of wages paid to workers and investment for future periods must be financed by working capital (i.e., $\ell = wh$, where w is the wage rate and

h is hours). Both intertemporal debt and intratemporal working capital loans are governed by a collateral constraint (note that intertemporal debt chosen in this period is constrained by next period's collateral constraint).

$$(1 + r_n)\ell \leq \begin{cases} \xi_n(a)(1-\delta)k + b, & b \leq 0 \\ \\ \xi_n(a)(1-\delta)k, & b > 0 \end{cases} \tag{3.45}$$

Here intratemporal debt, which is strictly positive, always counts against this constraint. However, intertemporal debt can be negative (in which case it is savings), which can also be used as collateral, but only to a limited extent. When intertemporal debt is negative, it counts fully against the constraint. A key point here is that the savings rate r differs from the lending rate r_n, so the return to b varies based on whether debt is positive or negative:

$$q(b) = \begin{cases} \frac{1}{1+r_n}, & b \geq 0 \\ \\ \frac{1}{1+r}, & b < 0 \end{cases}$$

This is also reflected in the collateral constraint: firm liabilities include interest due at the lending rate r_n, while interest at rate r are pledgable along with the principle if b is positive.

Also, incorporated in this setup is a relationship age a. As this age evolves, collateral constraints loosen, due to an unmodeled contract under which interest rates remain constant but collateral requirements slacken. In other words, banks offer contracts in a competitive environment that allow for increased access to credit over time. This age of relationship evolves naturally:

$$a' = \begin{cases} a + 1, & w/\ prob\ \chi \\ \\ 0, & w/\ prob\ (1-\chi) \end{cases}$$

In the calibration that follows, the function that governs the change in $\xi(.)$ with a is a simple linear function until age three where it reaches it's maximum:

$$\xi(a) = \begin{cases} \frac{(2-a)}{2}\xi_{min} + \frac{a}{2}\xi_{max}, & a < 3 \\ \\ \xi_{max}, & a \geq 3 \end{cases} \tag{3.46}$$

This setup incorporates a second type of segmentation: one that is dependent on the length of the relationship. Essentially, the evolving collateral constraint in the contract embodies "soft" information gathered by the bank over the term of the contract with the firm. As the bank learns more about the firm, the bank is able to extend more credit to the firm. However, with probability $1 - \chi$, the relationship is exogenously dissolved.

Furthermore, I need to specify an AR(1) process for the firm TFP process:

$$log(z_i') = \nu + \varphi log(z_i) + \epsilon \quad \epsilon \sim N(0, \sigma) \tag{3.47}$$

Channels for interest rate shocks to affect both demand and supply for credit now in place. The interest rate directly impacts the incentive to accumulate capital via the budget constraint in (3.44), which in turn should lead to lower capital, which can potentially tighten (3.45) in future periods, thereby reducing credit demand. It remains a quantitative question, now, as to which effect will dominate.

3.5.3   Final Goods Producer and Pricing

Additionally, revenue is not solely determined by production, but also prices. Prices differ since goods are differentiated. I use a monopolistic competition frame-

work with the following simplified aggregator.

$$Y = \int_i y_i^\rho \, di \tag{3.48}$$

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. Thus, I have the following problem for the final producer:

$$\max_{\{y_i\}} \int_i y_i^\rho \, di - \int_i p_i y_i \, di \tag{3.49}$$

This will yield a pricing function given by (which is decreasing in own output since $\rho < 1$):

$$p_i = (y_i)^{\rho - 1} \tag{3.50}$$

3.5.4 Entrepreneur Life Cycle Dynamics

To characterize an equilibrium, I will need to specify a process for firm dynamics. I use the approach of recycling capital from dying firms for new firms. Each period, a measure $1 - \zeta$ firms die exogenously. I assume a fixed amount is given to new firms to start. Thus, each entrant begins their life with capital:

$$k_{ent} = \bar{k} \tag{3.51}$$

Where $\bar{k}$ is a fixed parameter that I calibrate.

3.5.5 Banks

There is a continuum of unit mass of banks on each island that compete over lending opportunities to firms. Since each bank has zero mass, they take prices as given. Additionally, since there is no entry or exit of banks on the island, I can characterize the financial sector with a representative bank. This representative bank's problem is given by:

$$\pi_n(L_n; r_d, r_n) = \max_{L_n} L_n(r_n - r_d) - \Gamma_n \frac{L_n^{1+\gamma}}{1+\gamma} \tag{3.52}$$

where L_n is the total amount of lending on island n. Here, the parameters Γ_n and γ govern the cost of lending on island n (note that Γ_n potentially varies across islands). First order conditions imply:

$$r_n = r_d + \Gamma_n L_n^{\gamma} \tag{3.53}$$

Thus, Γ_n creates a spread between the deposit rate and the lending rate on island n that is potentially also dependent on loan volume. For simplicity, consider the case where $\gamma = 0$. Then $r_n = r_d + \Gamma_n$, and Γ_n is the constant spread of the lending rate over the interest rate. While the deposit rate and lending rate will ultimately be determined in equilibrium (using both the household and producer problems), the spread will be determined in part by the finance sector, and in the special case, it is entirely determined by the finance sector. In this case, if I hold deposit rates constant (as in steady state) Γ_n will directly translate into differences in interest rates.

3.5.6 Financial Market Equilibrium

Implicit in the problem above is that total lending is equal to deposits, or $\sum_n L_n = D$. It should be noted that bank lending L_n is equal to both intertemporal debt and intratemporal debt. Likewise, deposits are the sum of all household savings and producer savings. That is, in each period (dropping time subscripts):

$$\sum_n L_n = \int_i [b_i \Upsilon(b_i) + \ell_i] \, di = s - \int_i b_i(1 - \Upsilon(b_i)) di = D \tag{3.54}$$

where i is the index for producers, s is household savings, and b_i is debt outstanding. $\Upsilon(.)$ is an indicator function, which is 1 when b_i is positive (borrower) and 0 when b_i is negative (saver). Rearranging, I have:

$$s = \int_i [b_i + \ell_i] \, di \tag{3.55}$$

Thus, savings by households accounts for the disparity between corporate savings and corporate borrowing. Without idiosyncratic risk, both b_i and ℓ_i would be weakly positive, and all savings would be from the household sector. However, the potential for negative shocks allows for cases where producers want to save, which leads to negative values of b_i. Together with the profit maximization problem of banks from the previous section and borrowing/lending decisions by households and firms, these equations characterize an equilibrium in financial markets.

In summary, banks simply act as conduits for savings to find borrowers. However, this incurs a cost, parameterized by Γ_n and γ, which creates a spread between lending and borrowing rates. Furthermore, banks allocate savings by households and some producers between intertemporal loans to other producers and intratem-

poral loans by producers. Thus, all three sets of agents potentially have a hand in determining lending supply.

3.6   Calibration Strategy

In this calibration, I consider a case with two islands. In the baseline, they are identical with the exception that there is a 50 basis point higher interest rate on one island. In my calibration, I benchmark parameters to either 2005 data from the US, or to long-run pre-crisis averages from the US. Model parameters, along with targets and the results of the calibration, are listed in Table 3.1.

The first two are relatively straightforward parameters, with targets taken from standard references in the literature or readily available data, (note that the choice of ρ and α should be chosen jointly). I pick a death rate of 10% as a relatively standard value, although a more careful calibration taking into account age-dependency using the Business Dynamics Statistics from the Census Bureau could be used. I calibrate the bank separation rate to data from my own calculations of the SSBF (note that this parameter should be chosen jointly with the death rate). I specify a CRS banking sector in the model. Depreciation is chosen based on Cooper and Haltiwanger (2006).

The persistence of firm productivity is chosen from a range of estimates in the literature. There is substantial debate as to the best choice. I pick a relatively down-the-middle value.

Finally, each of the last five parameters are chosen jointly to match the relative

Table 3.1: Targets for Calibration

Parameter	Value	Target Criteria/Source	Model
ρ	0.9091	10 % Markups: Basu and Fernald (1997)	
α	0.3243	60% labor income share:	
		Cooley and Prescott (1995)	
β	0.9615	Annual savings rate of 4%	
ζ	0.9	10% death rate	
χ	0.95	7.8 year avg. relationship: SSBF	
γ	0	CRS banking markets	
φ	0.8		
δ	0.069	Cooper and Haltiwanger (2006)	
$\bar{k}$	0.197	0.3 Relative Entrant Size (BDS)	0.22
ϕ	2.05	Hours = 0.64	0.64
σ	0.1	0.337 S.D. of (i/k):	0.40
		Cooper and Haltiwanger (2006)	
ξ_{min}	0.5	0.4: Med. Leverage for	0.45
		new bank relationships (SSBF)	
ξ_{max}	0.9	0.8: Med. Leverage for	0.79
		old bank relationships (SSBF)	

size of entrants to the average firm size, number of hours, standard deviation of investment rates, and leverage over relationship length (which I calculated using the Survey of Small Business Finances (SSBF)).

3.7   Quantitative Results

In this section I conduct two sets of exercises, one under partial equilibrium and one under general equilibrium, and explore the results of three experiments in each. In each set of exercises, I first increase the interest rate on both islands, but one island will be hit by a larger shock (1% vs. 2 %). Next, I consider a collateral constraint shock where each value of the function $\xi(a)$ is tightened. Again, on one island, there is a tighter constraint. On the island with initially lower interest rates, the constraint tightens proportionally (for each a) by 2 % ($\kappa_n = 0.98$). On the island with higher interest rates, the constraint tightens by 4% ($\kappa_n = 0.96$).Finally, I consider a separation rate shock, where financial separations begin to take place more frequently on both of the islands. Again, in this case the island with lower interest rates experiences a small increase in the separation rate to 7%, while the island with tighter constraints experiences a larger increase to 13%.

In what follows, I first conduct a partial equilibrium exercise where I hold the distribution over capital and productivity constant (as well as wages and deposit rates) to investigate several financial shocks in the initial period of the shock. This exercise is valid for thinking about the initial impact on labor and capital productivity before firms have had time to adjust their capital stocks. Then I will explore

long-run steady state effects relative to the baseline given the changes in financial parameters. With respect to the timing of firm responses, the two sets of exercises focus on the extreme short run and the extreme long run. There may be additional implications in the medium-run as the economy adjusts to the shock which will not be captured in either experiment. While the short and long-run are instructive for what to expect over the horizon of a recession, it is likely important to take into account transition dynamics. I leave the exploration of these issues to future work.

3.7.1   Partial Equilibrium: Initial Impact

In this section, I provide results on the initial steady state regime, then three partial equilibrium exercises where the shifts in parameters described above transpire, but capital stocks have not had time to adjust. Additionally, deposit rates and wages are set, so no adjustment in prices can mitigate the effect on quantities. Conceptually, this is similar to the analytical section in that most arguments are made holding the distribution constant, and abstracting from aggregate price changes. It can be thought of the initial impact of the financial shock.

Table 3.2 displays results for the baseline and the partial equilibrium outcomes. I display results for output, hours, capital, the aggregate debt/asset ratio, and TFP. TFP is defined as $Z = Y/(K^\alpha H^{1-\alpha})$, where Y is aggregate output, H is aggregate labor, and K is the aggregate capital stock. Each shock induces a decline in output and hours. The interest rate shock generates a mild decline of output by 1.3% and a decline of employment by 2.2%. By construction capital remains constant, while

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TFP rises slightly.

A tighter collateral constraint schedule induces a massive decline in output and hours. In part, this is due to the sticky price, but it is illustrative of the potency of tightening in the extensive margin of credit. It does generate a sizable increase in TFP, which is likely due to the decline in capital productivity dispersion (see the next section).

Table 3.2: **Partial Equilibrium Results: Initial Impact**

Shock	Output	Debt/Asset	Labor	Capital	TFP
Baseline	0.844	0.756	0.641	1.288	1.051
High Interest Rate	0.833	0.753	0.626	1.288	1.053
Tight Collateral Constraint	0.598	0.577	0.371	1.288	1.075
High Bank Separation	0.815	0.740	0.614	1.288	1.045

Likewise, a higher bank separation rate generates a sizable decline in output (3.5%) and employment (4.2%). Leverage declines mildly, and there is modest impact on TFP, which declines by 0.6%. Again, this decline is likely due to the correlation between the decline in the collateral constraint among long-lived relationships and productivity. That is, more productive firms are impacted by the higher rate of separation.

I now turn to dispersion in labor productivity in each of these experiments.

Table 3.3 displays the variance decomposition discussed in the analytical section for the baseline economy and the partial equilibrium analysis. These values are inclusive of the measure of firms μ_n that are constrained. For example, the contribution of the constrained distribution is the average contribution of $\mu_n \sigma_{n,con}^2$ Under the baseline, there is a fair amount of dispersion in labor productivity, which is entirely due to financial frictions in this economy. Overall, the standard deviation of labor productivity is about 20 log points. Additional frictions could be added to induce higher dispersion.

In general, I find very little cross-island dispersion. At most, the standard variance in the high bank separation rate case generates a standard deviation of about 2 log points, and still contributes less than 1% of the variance. Much of within island dispersion is concentrated amongst constrained firms, contributing at least 3/4 of the variance in each case.

Consistent with the partial equilibrium analysis conducted previously, overall dispersion falls in response to an interest rate shock, despite the fact that the cross-island dispersion rises due to heterogeneity of the shock. Furthermore, dispersion rises for both the uniform decline in collateral constraints and the shock to bank separations, which is consistent with rising within-island dispersion seen in the decomposition. Although the contribution of constrained dispersion rises by more in response to the tighter collateral constraint schedule, the separation shock generates significant increases in relative means and a slight rise in cross-island dispersion, generating higher overall dispersion in response to the high separation rate. Also consistent with the analytical section is the change in the share of constrained firms,

Table 3.3: **Initial Impact on Variance Decomposition of Log Labor Productivity**

Variance	Shock			
Contribution	Baseline	High IR	Tight CC	High Bank Separation
Total Dispersion	0.0396	0.0387	0.0582	0.0645
Between-Island	0.0000	0.0000	0.0000	0.0004
	(0.00%)	(0.04%)	(0.00%)	(0.65%)
Within-Island	0.0396	0.0387	0.0582	0.0640
	(100.00%)	(99.96%)	(100.00%)	(99.35%)
Constrained	0.0299	0.0293	0.0477	0.0492
Dispersion	(75.51%)	(75.51%)	(82.04%)	(76.34%)
Constrained	0.0039	0.0040	0.0010	0.0057
Relative Mean	(9.88%)	(10.24%)	(1.71%)	(8.84%)
Unconstrained	0.0058	0.0055	0.0095	0.0091
Relative Mean	(14.61%)	(14.21%)	(16.25%)	(14.18%)
$\mu_{\mathbf{n}}$ (constrained share)	59.66%	58.12%	90.50%	61.56%

which falls in response to the interest rate shock, but rises in response to tighter collateral constraints and higher bank separation.

3.7.1.1 Capital Productivity

Although I have mostly focused on labor productivity in my analytical work, there are also implications for other marginal revenue products. I now shift focus to capital productivity, the focus of Gopinath et al. (2017), and Table 3.4 displays the variance decomposition of log revenue per unit of capital ($log\left(\frac{p_i y_i}{k_i}\right)$). Here, capital productivity exhibits about twice as much dispersion as labor, which is primarily due to the time-to-build assumption, where capital is chosen before productivity shocks are realized. This not only creates dispersion among constrained firms, but also unconstrained firms. Additionally, because capital is owned and not rented, it takes time to accumulate the desired or optimal stock.

Again, little of the dispersion in capital productivity is due to cross-island dispersion. Oddly, dispersion in capital productivity rises in response to an interest rate shock but falls in response to tighter collateral constraints, which is consistent with changes in TFP. Dispersion of capital productivity rises significantly in response to a separation shock, which is consistent with the decline in aggregate TFP.

3.7.2 Long-run Regime

In the long run, firms adjust to shifts in financial conditions. These responses generate changes in the distribution of firms, and so it is inappropriate to utilize

Table 3.4: **Initial Impact on Variance Decomposition of Log Capital Productivity**

Variance	Shock			
Contribution	Baseline	High IR	Tight CC	High Bank Separation
Total Dispersion	0.1548	0.1569	0.1392	0.2148
Between-Island	0.0000	0.0000	0.0000	0.0008
	(0.00%)	(0.00%)	(0.02%)	(0.39%)
Within-Island	0.1548	0.1569	0.1391	0.2140
	(100.00%)	(99.17%)	(99.99%)	(99.61%)
Constrained	0.1076	0.1071	0.1321	0.1792
Dispersion	(69.51%)	(68.24%)	(97.21%)	(83.43%)
Unconstrained	0.0239	0.0140	0.0005	0.0073
Dispersion	(15.44%)	(8.90%)	(0.39%)	(3.39%)
Constrained	0.0094	0.0101	0.0001	0.0046
Relative Mean	(6.07%)	(6.41%)	(0.04%)	(2.13%)
Unconstrained	0.0139	0.0140	0.0005	0.0073
Relative Mean	(8.98%)	(8.90%)	(0.39%)	(3.39%)
$\mu_{\mathbf{n}}$ (constrained share)	59.66%	58.12%	90.50%	61.56%

my analytical predictions and partial equilibrium results for persistent shocks. In these sets of experiments, I consider steady state equilibria given the same shocks described above, which are assumed to persist indefinitely. Table 3.5 presents aggregate values from the baseline and three alternative regimes, again highlighting output, leverage, and productivity. In this case, the economy has responded to the shock and arrived at the new steady state.

Table 3.5: **Long-run Regime Comparisons**

Regime	Output	Debt/Asset	Labor	Capital	TFP
Baseline	0.844	0.756	0.641	1.288	1.051
Interest Rate Shock	0.832	0.750	0.638	1.224	1.055
Tight Collateral Constraint	0.838	0.738	0.639	1.272	1.050
High Bank Separation	0.827	0.726	0.637	1.229	1.049

Across the new regimes there are substantial declines in output, labor and capital. The regime with a high interest rate generates an output decline of 1.5%, an employment decline of 0.4%, and a decline in the capital stock of about 5%. Additionally, TFP rises by a modest 0.4%, which as can be seen in Table 3.6 as dispersion falls substantially.

In the tight collateral constraint regime, output falls by 0.8%, employment falls by about 0.3%, and capital declines by 1.2 %. The incentive to accumulate

capital in order to loosen the constraint keeps capital from falling as much in this regime, and so labor does not fall by much more than in the interest rate regime. TFP declines slightly, reflecting rising labor but falling capital dispersion.

In the high separation rate regime, output falls by a little over 3%, with labor falling by 0.6%, and capital dropping by 4.6%. This translates into a small decline in TFP of 0.2%.

These results reflect changes in the distribution of firms which can be seen in Table 3.6. Again, below is the decomposition proposed in the analytical section. Here, the distributional changes are similar to that of the partial equilibrium section. Relative to Gopinath et al. (2017), these results are consistent with the effect of an interest rate shock: higher interest rates lead to long-run declines in productivity dispersion. Additionally, I also find there is an increase in dispersion in response to a uniform collateral constraint shock, as well as to a bank separation shock.

3.7.2.1   Capital Productivity

in Table 3.7, I explore the implications of each regime for capital productivity (this is the most closely related exercise to Gopinath et al. (2017)). As before, there is substantially more dispersion in capital productivity. Again, dispersion either falls modestly, as in the high interest rate regime and tight collateral constraint regime, or rises slightly, as in the high separation regime. The decline in dispersion in the collateral constraint regime is likely indicative of substantial changes in the composition of the firm distribution in response to the parameter shifts. Since most

Table 3.6: **Long-Run Variance Decomposition of Log Labor Productivity**

Variance	Regime			
Contribution	**Baseline**	**High IR**	**Tight CC**	**High Bank Separation**
Total Dispersion	0.0396	0.0351	0.0398	0.0397
Between-Island	0.0000	0.0000	0.0000	0.0000
	(0.00%)	(0.01%)	(0.02%)	(0.01%)
Within-Island	0.0396	0.0351	0.0398	0.0397
	(100.00%)	(99.99%)	(99.98%)	(100.00%)
Constrained Dispersion	0.0299	0.0261	0.0381	0.0284
	(75.51%)	(74.51%)	(95.60%)	(71.71%)
Constrained Relative Mean	0.0039	0.0035	0.0002	0.0045
	(9.88%)	(10.10%)	(0.43%)	(11.43%)
Unconstrained Relative Mean	0.0058	0.0054	0.0016	0.0067
	(14.61%)	(15.39%)	(3.97%)	(16.86%)
$\mu_{\mathbf{n}}$ (constrained share)	59.66%	60.35%	90.33%	59.72%

firms are constrained, the impact on dispersion is solely through the dispersion among constrained firms. Unlike in Gopinath et al. (2017), the majority of my firms are constrained to begin with, and more become constrained with collateral constraint shocks. Together with results from previous research, this potentially suggests dispersion is non-monotonic in the share of constrained firms.

3.7.2.2   The Cross-Island Channel

In both the partial equilibrium and long-run steady state results, it is still the case that within-island dispersion drives overall dispersion. Cross-island dispersion continues to be muted. In order to better understand the conditions under which cross-island dispersion matters, I consider a couple of partial equilibrium cases.

Exercise 1

First, I ask the question under what circumstances will the cross-island dispersion generated by a heterogeneous interest rate shock swamp the decline in within-island dispersion. In other words, how big does the gap between island borrowing rates need to be to generate enough cross-island dispersion to overcome the decline in within-island dispersion associated with the shock. Specifically, I hold the interest rate on island 1 constant at 4.5%, and increase the interest rate on island 2 until dispersion is the same as in the baseline (again holding the distribution and wages constant). I find that an increase of 25 *percent* is necessary to generate enough cross-island dispersion to reach this level. At this point, the normalized cross-island means term is equivalent to about 7 log points, and contributes about 15% of the

Table 3.7: **Long-run Variance Decomposition of Log Capital Productivity**

Variance	Regime			
Contribution	**Baseline**	**High IR**	**Tight CC**	**High Bank Separation**
Total Dispersion	0.1548	0.1402	0.1512	0.1561
Between-Island	0.0000	0.0012	0.0003	0.0004
	(0.00%)	(0.83%)	(0.32%)	(0.28%)
Within-Island	0.1548	0.1390	0.1511	0.1557
	(100.00%)	(99.17%)	(99.97%)	(99.72%)
Constrained	0.1076	0.0931	0.1286	0.1143
Dispersion	(69.51%)	(66.44%)	(85.05%)	(73.22%)
Unconstrained	0.0239	0.0149	0.0151	0.0105
Dispersion	(15.44%)	(10.64%)	(9.96%)	(6.71%)
Constrained	0.0094	0.0098	0.0016	0.0070
Relative Mean	(6.07%)	(6.99%)	(1.07%)	(4.46%)
Unconstrained	0.0139	0.0149	0.0151	0.0242
Relative Mean	(8.98%)	(10.64%)	(9.96%)	(15.48%)
$\mu_{\mathbf{n}}$ (constrained share)	59.66%	60.35%	90.33%	59.72%

total variance.

Exercise 2

Another experiment is to ask under what *combination* of shocks would cross-island dispersion begin to matter. In particular, since the separation rate seems to generate higher contributions of between dispersion, and higher interest rate dispersion necessarily translates into higher cross-island dispersion, a combination of an heterogeneous interest rate shock and a separation shock could induce higher between dispersion. Specifically, the exercise consists of finding the shift in interest rate on island 2 under the heightened bank separation rates considered earlier (7% on island 1 and 13 % on island 2) would the resulting between-island dispersion in exercise 1. I find that an increase of 19%, as opposed to 25%, is required in this case. While this is still a substantial increase in borrowing costs, it suggests that these frictions can interact to increase the relative contribution of between-island dispersion to overall variance.

3.8 Conclusion

This paper presents a framework for evaluating the impact of financial market segmentation and financial shocks on aggregate and micro-level outcomes. I show that labor productivity dispersion can be decomposed into within-geography and between-geography components, and that the within component is generally dominant. Furthermore, I show that different types of financial shocks have different implications for the initial impact on labor productivity dispersion. However, there

is potential in the long run for many of these effects to be mitigated by the changing distribution of firms.

These results provide simple predictions for the impact of financial shocks on within-location productivity patterns. Given the evidence on initial impact of financial shocks, one would expect geographies hit by interest rate shocks to behave differently (exhibiting a decline in dispersion) relative to geographies hit by bank separation or collateral constraint shocks (which would exhibit an increase in dispersion). Researchers should consider using microdata on firm labor productivity could be used to implement a strategy that examines the patterns of labor productivity dispersion in response to proxies for financial shocks.

Appendix A: 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

Appendix B: 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 (2017) and examine whether the interaction considered above is influenced.

B.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.[1] Secondly, 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,

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[1]Davis and Haltiwanger (2017) 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).

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.

B.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, 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.

B.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. (2014), 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.

B.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.

Appendix C: 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/Small	Old/Large
OLS				
Adjusted R^2	0.039	0.013	0.031	0.021
N	26,440,000	7,860,000	16,310,000	2,270,000
IV				
Centered R^2	0.040	0.013	0.032	0.021
N	18,520,000	5,700,000	11,290,000	1,530,000

Table C.1: R^2 of Main House Price Regressions

	Young	Old/Small	Old/Large
OLS			
Adjusted R^2	0.013	0.031	0.021
N	7,860,000	16,310,000	2,270,000
Total IV			
Centered R^2	0.013	0.032	0.021
N	5,700,000	11,290,000	1,530,000

Table C.2: R^2 of Main House Price/Mortgage Share Regressions

	Young	Old/Small	Old/Large
OLS			
Adjusted R^2	0.013	0.031	0.021
N	7,860,000	16,310,000	2,270,000
Instrumented HPI			
Centered R^2	0.013	0.032	0.021
N	5,700,000	11,290,000	1,530,000
Instrumented Bank Exit			
Centered R^2	0.013	0.031	0.023
N	7,860,000	16,310,000	2,270,000
Instrumented HPI and Bank Exit			
Centered R^2	0.013	0.032	0.021
N	5,700,000	11,290,000	1,530,000

Table C.3: R^2 of Main House Price/Bank Exit Regressions

	Total	Young	Old/Small	Old/Large
IV				
F-Stat	103.6	99.9	100.8	121.7
N	18,520,000	5,700,000	11,290,000	1,530,000

Table C.4: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Main House Price Regressions

	Young	Old/Small	Old/Large
Total IV			
K-P F-stat	12.0	14.8	16.3
HPI A-P F-stat	67.3	69.2	36.0
HPI*MTG_RATIO A-P F-stat	21.4	25.6	15.1
N	5,700,000	11,290,000	1,530,000

Table C.5: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Main House Price/Mortgage Share Regressions

	Young	Old/Small	Old/Large
Instrumented HPI			
F-stat	99.9	99.9	121.0
N	5,700,000	11,290,000	1,530,000
Instrumented Bank Exit			
K-P F-stat	17.3	13.7	11.2
N	7,860,000	16,310,000	2,270,000
K-P F-stat	13.8	11.0	17.5
$\hat{HPI}$ A-P F-stat	16.0	12.6	11.3
$\hat{BE}$ A-P F-stat	15.3	11.9	19.8
N	5,700,000	11,290,000	1,530,000

Table C.6: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Main House Price/Bank Exit Regressions

Appendix D: Tradable Sector Results

Restricting the sample of industries under consideration to those in the trad-able 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 par-ticular, 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/Small	Old/Large
OLS				
△ HPI	0.1041***	0.2956***	0.0562**	-0.0046
	(0.0243)	(0.0614)	(0.0241)	(0.0424)
N	1,250,000	240,000	880,000	130,000
IV				
△ HPI	0.1733***	0.4900***	0.0440	-0.0755
	(0.0590)	(0.1618)	(0.0640)	(0.1273)
N	870,000	170,000	620,000	80,000

Table D.1: Employment Growth Regressions on House Prices, grouped by firm age/size

	Young	Old/Small	Old/Large
OLS			
△ HPI	0.3021***	0.0552**	-0.0054
	(0.0626)	(0.0241)	(0.0418)
Bank Exit	0.1606**	-0.0367*	-0.0324
	(0.0726)	(0.0222)	(0.0512)
N	240,000	880,000	130,000
Instrumented HPI			
$\triangle \hat{HPI}$	0.4917***	0.0435	-0.0765
	(0.1606)	(0.0647)	(0.1270)
Bank Exit	0.1821**	-0.0464*	-0.0229
	(0.0843)	(0.0250)	(0.0644)
N	170,000	620,000	80,000
Instrumented Bank Exit			
△ HPI	0.2726***	0.0519**	-0.0067
	(0.0612)	(0.0233)	(0.0411)
$\hat{BE}$	-0.5711**	-0.1529	-0.0868
	(0.2524)	(0.1107)	(0.2147)
N	240,000	880,000	130,000
Instrumented HPI and Bank Exit			
$\triangle \hat{HPI}$	0.5314***	0.0620	0.0128
	(0.1395)	(0.0567)	(0.1190)
$\hat{BE}$	0.0104	-0.3260**	0.2343
	(0.5114)	(0.1617)	(0.3150)
N	170,000	620,000	80,000

Table D.2: Employment Growth Regressions on Bank Exit by Firm Age/Size

	Young	Old/Small	Old/Large
OLS			
△ HPI	0.4198***	0.1533***	0.0485
	(0.0977)	(0.0452)	(0.0640)
△ HPI*	0.1340	0.1120***	0.0639
MTG_RATIO	(0.0875)	(0.0373)	(0.0629)
N	240,000	880,000	130,000
Total IV			
△ HPI	-0.1240	0.1913	0.3538
	(0.4795)	(0.1631)	(0.3158)
△ HPI*	-0.5815	0.1385	0.4105
MTG_RATIO	(0.3865)	(0.1193)	(0.2685)
N	170,000	620,000	80,000

Table D.3: Employment Growth Regressions on House Price/Mortgage Share Interactions by Firm Age/Size

	Total	Young	Old/Small	Old/Large
OLS				
Adjusted R^2	0.050	0.015	0.039	0.013
N	1,250,000	240,000	880,000	130,000
IV				
Centered R^2	0.052	0.026	0.042	0.026
N	870,000	170,000	620,000	80,000

Table D.4: R^2 of Tradable House Price Regressions

	Young	Old/Small	Old/Large
OLS			
Adjusted R^2	0.015	0.039	0.013
N	240,000	880,000	130,000
Instrumented HPI			
Centered R^2	0.026	0.042	0.026
N	170,000	620,000	80,000
Instrumented Bank Exit			
Centered R^2	0.028	0.042	0.034
N	240,000	880,000	130,000
Instrumented HPI and Bank Exit			
Centered R^2	0.026	0.042	0.026
N	170,000	620,000	80,000

Table D.5: R^2 of Tradable House Price/Bank Exit Regressions

	Young	Old/Small	Old/Large
OLS			
Adjusted R^2	0.015	0.039	0.013
N	240,000	880,000	130,000
Total IV			
Centered R^2	0.026	0.042	0.026
N	170,000	620,000	80,000

Table D.6: R^2 of Tradable House Price/Mortgage Share Regressions

	Total	Young	Old/Small	Old/Large
IV				
F-Stat	96.9	130.6	88.3	91.7
N	870,000	170,000	620,000	80,000

Table D.7: First Stage Kleibergen-Paap rk Wald F-stat of Tradable House Price Regressions

	Young	Old/Small	Old/Large
Instrumented HPI			
F-stat	131.9	86.1	89.8
N	170,000	620,000	80,000
Instrumented Bank Exit			
K-P F-stat	18.5	15.0	25.9
N	240,000	880,000	130,000
Total IV			
K-P F-stat	9.8	9.6	18.8
$\hat{HPI}$ A-P F-stat	16.7	10.7	8.4
$\hat{BE}$ A-P F-stat	11.9	10.1	20.5
N	170,000	620,000	80,000

Table D.8: First Stage Kleibergen-Paap rk Wald and Angrist-Pischke F-stats of Tradable House Price/Bank ExitRegressions

	Young	Old/Small	Old/Large
Total IV			
K-P F-stat	11.8	12.9	17.4
HPI A-P F-stat	105.6	108.6	39.8
HPI*MTG_RATIO A-P F-stat	35.4	41.4	23.1
N	170,000	620,000	80,000

Table D.9: First Stage Kleibergen-Paap rk Wald and Angrist Pischke F-stats of Tradable House Price/Mortgage Share Regressions

Appendix E: Firm Results

These results reflect regressions similar to those run in the main text, but where the unit of observation is now the firm. In these regressions, assumptions are made for firm location and industry based on modal employment. The county with the largest share of employment is assumed to be the firm's location, and likewise the firm's industry is assumed to be the industry with the largest share of employment in the firm. These results are broadly consistent with the results in the main text, although the results for old/large businesses are even weaker.

	Total	Young	Old/Small	Old/Large
OLS				
△ HPI	0.1235***	0.1694***	0.1114***	-0.0080
	(0.0305)	(0.0346)	(0.0288)	(0.0464)
Firm-Year Obs.	16,530,000	4,750,000	11,740,000	50,000
IV				
$\triangle \widehat{HPI}$	0.1446***	0.1976***	0.1347**	-0.1136
	(0.0504)	(0.0597)	(0.0519)	(0.1014)
Firm-Year Obs.	11,730,000	3,480,000	8,220,000	30,000

Table E.1: Firm-Level 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.

	Young	Old/Small	Old/Large
OLS			
$\triangle$ HPI	0.2604***	0.1643***	0.0030
	(0.0391)	(0.0228)	(0.0552)
$\triangle$ HPI*	0.1109***	0.0675***	0.0126
MTG	(0.0340)	(0.0259)	(0.0485)
Firm-Year Obs.	4,750,000	11,740,000	50,000
IV			
$\triangle HPI$	0.3020**	0.3127***	-0.0027
	(0.1304)	(0.0987)	(0.2115)
$\triangle$ HPI*	0.1311	0.1933**	0.0617
MTG	(0.1048)	(0.0852)	(0.1882)
Firm-Year Obs.	3,480,000	8,220,000	30,000

Table E.2: Firm-Level 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. $\triangle \widehat{HPI}$ indicates house prices instrumented by changes in state unemployment interacted with Saiz elasticities.

	Young	Old/Small	Old/Large
OLS			
$\triangle$ HPI	0.1682***	0.1097***	-0.0079
	(0.0346)	(0.0285)	(0.0467)
Bank Exit	-0.0400	-0.0555***	0.0048
	(0.0245)	(0.0129)	(0.0373)
Firm-Year Obs.	4,750,000	11,740,000	50,000
Instrumented HPI			
$\triangle\widehat{HPI}$	0.1966***	0.1341***	-0.1140
	(0.0598)	(0.0515)	(0.1017)
Bank Exit	-0.0452	-0.0581***	-0.0113
	(0.0278)	(0.0140)	(0.0455)
Firm-Year Obs.	3,480,000	8,220,000	30,000
Instrumented Bank Exit			
$\triangle$ HPI	0.1662***	0.1060***	-0.0115
	(0.0359)	(0.0290)	(0.0481)
$\widehat{BE}$	-0.1075	-0.1834**	-0.1223
	(0.1346)	(0.0868)	(0.1807)
Firm-Year Obs.	4,750,000	11,740,000	50,000

Table E.3: Firm-Level 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.
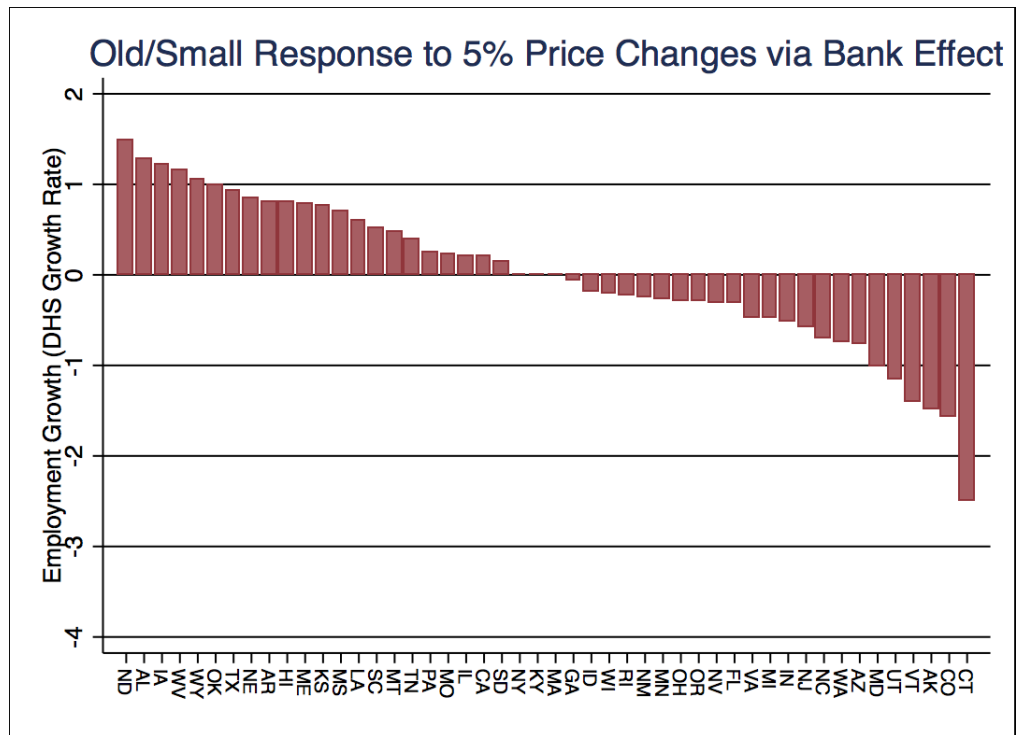
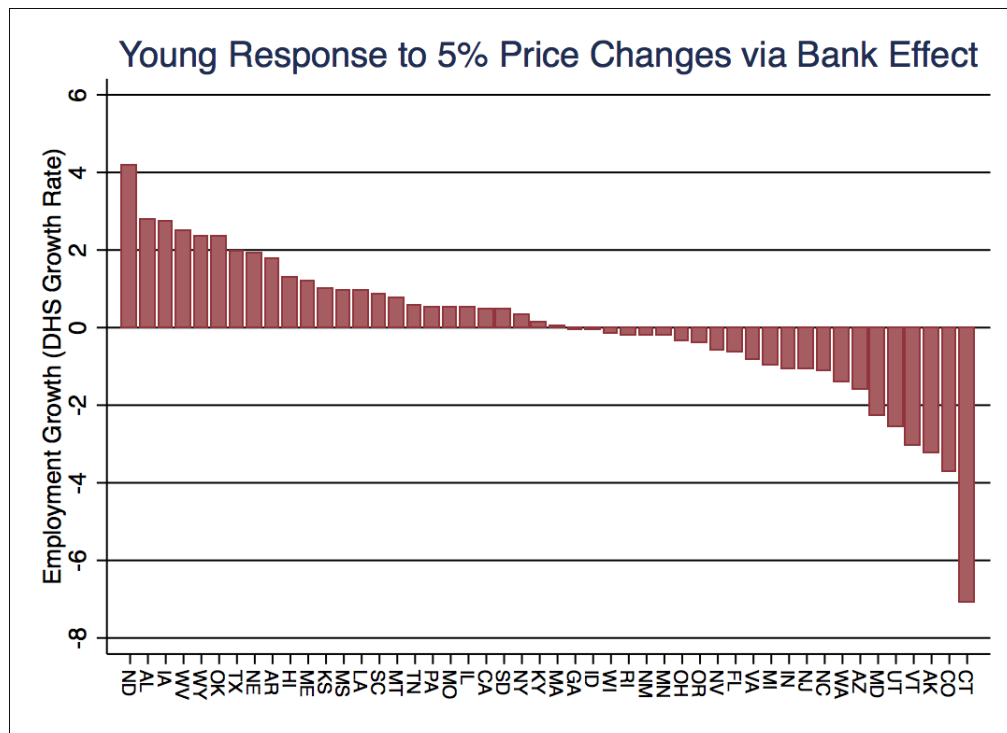Figure E.1: Effect of 5% HPI Change on Firm-level DHS Employment Growth, Old/Small Firms

Figure E.2: Effect of 5% HPI Change on Firm-level DHS Employment Growth, Young Firms
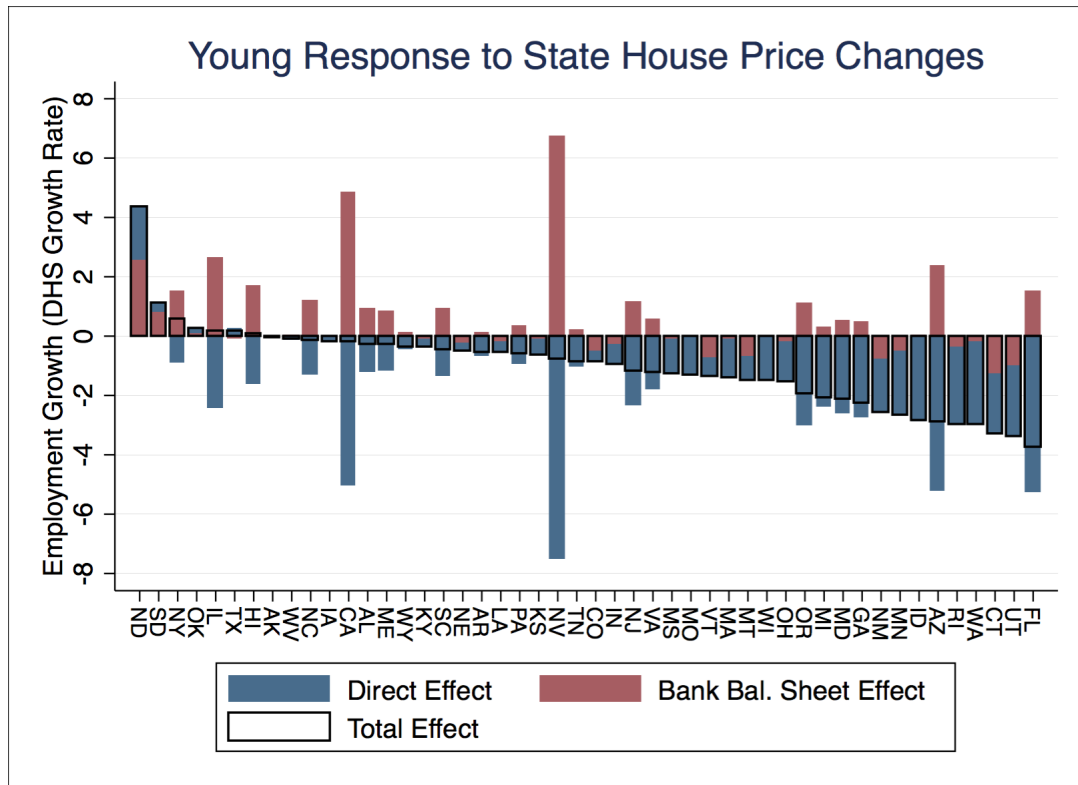
Figure E.3: Effect of Average State-Level HPI Change on Firm-level DHS Employment Growth, Old/Small Firms

Figure E.4: Effect of Average State-Level HPI Change on Firm-level DHS Employment Growth, Young Firms

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