How Credit Constraints Impact Job Finding Rates, Sorting & Aggregate Output*

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Abstract

We begin by examining the effect of consumer credit limits on job finding rates and the subsequent replacement earnings of displaced workers using new administrative data. We find that in response to an increase in credit limits equal to 10% of prior annual earnings, medium-tenure displaced mortgagors take .3 to 1 week longer to find a job but obtain an earnings replacement rate that is .5 to 1.5% greater. Compared to existing UI studies, $1 of unused credit is approximately one-fourth to one-half as potent as $1 of UI. We then construct a labor sorting model with credit which we use for two purposes. First, we use the model to provide a structural estimate of the duration and earnings elasticities, which we find to be .8 weeks and 0%, respectively. Second, we use the model to assess what happens to labor sorting, productivity, and the ensuing employment recovery if consumer credit limits contract during a recession. We find that when limits tighten during a downturn, employment rises but both productivity and output exhibit weaker recoveries. The tension between recovery speed and recovery health is due to the fact that when limits tighten, low-asset job losers are unable to self-insure. As a result, they search less thoroughly and take relatively more accessible jobs at less productive firms. Mechanically, standard measures of sorting improve.

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1 Introduction

Earnings losses after layoff are severe on average and differ significantly across individuals (Jacobson et al. [1993], Davis and Von Wachter [2011]).[1] While much is known empirically and theoretically about the impact of unemployment benefits on earnings losses (Ljungqvist and Sargent [1998], Saporta-Eksten [2013], Jarosch [2014]), little is known about the role consumer credit plays in the earnings losses of displaced workers, their job finding rates, the subsequent quality of jobs they take, and how this impacts the macroeconomy.

We merge 5 million proprietary individual credit reports with quarterly individual employment records from the Census based on social security numbers to measure the impact of consumer credit access on job finding rates and re-employment earnings of displaced workers. We find that when workers receive revolving credit lines worth 10% of pre-layoff annual labor earnings, medium-tenure displaced mortgagors take .3 to 1 week longer to find a job but obtain a .5 to 1.5% greater annual earnings replacement rate. These results are consistent with individuals using personal credit to fund longer unemployment spells so that they can search and find better job matches. To our knowledge, this is the first measure of the elasticity of job finding rates with respect to consumer credit access.

We then construct a model which we use for two purposes. First, we use the model to provide a structural estimate of the duration and earnings replacement elasticities with respect to credit limits. We estimate an elasticity of durations with respect to unused credit of .718 (implying about .8 week longer non-employment duration with a credit line worth 10% of prior income) that is straddled by our reduced form estimates. We also estimate an elasticity of earnings with respect to unused credit of approximately zero. Second, we use the model as a laboratory to answer the main question of what happens to labor sorting, productivity, and the ensuing employment recovery if consumer credit limits expand or contract during a recession.

We begin by introducing risk aversion into a search model with heterogeneous workers and firms (this is related to concurrent work with a theoretic emphasis by Eeckhout and Sepahsalari [2014] on savings and sorting). The model features directed search as in Menzio and Shi [2010, 2011] and labor market sorting, building on the influential work of Shimer and Smith [2000] and Shi [2001]. In our model, heterogeneous credit-constrained workers accumulate human capital while working. When unemployed, they direct their search for jobs among heterogeneous credit-constrained firms.

In the model, firms differ with respect to capital, and produce output by combining the human capital of workers with their own physical capital. We assume supermodularity, i.e. firms with greater amounts of capital produce more with workers who have greater amounts of human capital. Sorting in this context will therefore refer to the degree with which highly

[1] For structural approaches to this question, see also Jung and Kuhn [2012], Krolikowski [2013], Flaaen et al. [2013], and Huckfeldt [2014].

productive workers match with highly productive firms. In general, we will measure sorting in the model as either the raw correlation coefficient or *Spearman Rank correlation coefficient* between worker human capital and firm capital.[2] Which worker matches with which firm determines productivity in this economy, and therefore the ability of unemployed households to self-insure and search for higher quality jobs with firms has the potential to change the productivity of the economy.

The main experiment we conduct is to tighten borrowing limits during the 2007-2009 recession and then study the subsequent recovery. In particular, we simulate the 2007-2009 recession by using actual total factor productivity residuals in the model. During the recession, we permanently tighten borrowing limits, delivering a 3 percentage point reduction in the fraction of households borrowing, and a 1.1 percentage point reduction in the aggregate debt to income ratio. Upon impact and throughout the recovery, the tighter credit limit depresses labor productivity by .25 percentage points and decreases overall output by .1 percentage points. However, employment increases more quickly when debt limits are tighter. The mechanism is that when credit limits tighten, unemployed low-human-capital-borrowers lose their ability to self-insure and must take relatively abundant jobs at less-capital-intensive firms. In other words, constrained households take lower quality jobs, relatively quickly. As result, the recovery is quicker but not as healthy.

If we measure the recovery time as the time it takes to reach its pre-recession level, then tightening credit limits speeds up the recovery of labor market variables by 1 to 4 quarters. Capital and investment, however, recover as much as 6 quarters more slowly as households search for less-capital intensive jobs and entrepreneurs post more vacancies with less capital per vacancy. Since capital per worker declines, labor productivity also declines. While the number of employed workers increases, the increased employment does not offset this reduction in capital per worker, and so output declines.

In this economy, standard measures of sorting improve, even though output and productivity decline when debt limits tighten. This is because when debt limits tighten, constrained households take low productivity jobs (i.e. low capital jobs), but those with savings, who typically have high human capital, are able to continue to search thoroughly for high productivity jobs (i.e. jobs with greater capital). Since many of these constrained job losers are relatively unproductive workers and because we assume supermodularity in the production process, standard measures of sorting actually improve when credit limits tighten. In simple terms, productive workers continue to take productive jobs even when debt limits tighten, whereas unproductive workers become constrained when debt limits tighten and take relatively unproductive jobs. Sorting measures the correlation between human capital and capital, and this correlation actually increases when debt limits tighten. As we discuss in detail below, the presence of firm investment in the model disconnects the positive

[2]The Spearman Rank correlation coefficient is constructed heuristically as follows: rank all the workers in terms of human capital from 1 to N, rank all the firms in terms of physical capital from 1 to M, and then compute the corr(worker rank,firm rank) rather than computing corr(worker human capital, firm capital).

comovement of sorting, productivity, and output.

In our empirical work, we use a similar instrumental variable as Saiz [2010] and Mian and Sufi [2012] to identify the impact of credit constraints on labor market outcomes. The idea is to exploit variation in housing supply elasticities due to geography to separate out changes in worker quality from credit supply when examining employment related questions. We show that Saiz [2010]'s housing supply elasticity measure not only impacts house price growth but also subsequent credit access. In particular, the house supply elasticity has a strong impact on unused credit limits (our main endogenous independent variable). This geographically determined component of unused credit limits is plausibly exogenous to characteristics of the household, including employment prospects if we condition on the household not being employed in the construction or real-estate industry.

We then use this exogenous component of unused credit limits to examine what the impact is of credit on the job finding rates and earnings replacement rates of displaced workers. We follow the existing literature on earnings losses and restrict our sample to those with at least 3-years of tenure (dropping seasonal and low labor-force attachment individuals). In addition, given our identification strategy relies on the link between house prices and credit access, we restrict ourselves to displaced mortgagors. Our main measure of credit access is the unused revolving credit limit of an individual in the year prior to layoff expressed as a ratio of labor earnings in the year prior to layoff. We focus on revolving credit since this type of credit can be easily drawn on short notice, e.g. in response to job loss, and used without immediate payment due.

We find that among these displaced workers, personal credit affects job finding rates and the annual earning replacement rate. In response to an increase in credit limits equal to 10% of prior earnings, medium-tenure displaced mortgagors take .3 to 1 week longer to find a job. Relative to their prior annual earnings, an increase in credit limits equal to 10% of prior earnings allows them to find jobs that pay roughly .5% to 1.5% greater.[3] Workers with greater unused credit limits find jobs at larger, older firms. Since credit is unobserved in many datasets, this channel may help explain why wage outcomes of observationally identical individuals are so disperse (Mincer [1974], Haltiwanger et al. [2007]).

These results have several implications for the way both policy-makers and economists think about the optimal provision of unemployment insurance (Shimer and Werning [2005], Chetty [2008], Mitman and Rabinovich [2011], Michaillat [2012], Hsu et al. [2014]) and the response of labor markets to monetary policy (Bernanke and Blinder [1992], Doepke and Schneider [2006], Galí [2010], Gornemann et al. [2012], Auclert [2014]). The fact that increases in credit access can actually *reduce* job finding rates brings into question the ability of the Federal Reserve Bank to effectively meet the dual mandate of "maximum employment,

[3] If a layoff occurs in year t, replacement earnings are measured by taking the ratio of earnings in year t+1 to earnings in year t-1. Those without jobs have replacement earnings of zero. The result that unused credit improves earnings outcomes persists for any time horizon after the displacement. Dropping zeros strengthens the result.

stable prices and moderate long-term interest rates." Under our broader research agenda of how consumer credit impacts the real economy, we see these findings as shedding light on an important subcomponent of consumption smoothing which was previously neglected: the way job losers smooth consumption with private consumption smoothing mechanisms.

Our findings relate to the small but growing empirical literature on borrowing and consumption smoothing among the unemployed (Hurst and Stafford [2004], Crossley and Low [2005], Sullivan [2008], Herkenhoff and Ohanian [2012], Gerardi et al. [2013], Baker [2015], Baker and Yannelis [2015], Gelman et al. [2015]), as well as the well-developed empirical literature on earnings losses after layoff (see citations above). Our empirical contribution is to provide the first measure of the elasticity of job finding rates and replacement earnings with respect to unused credit limits.

Theoretically, our paper builds on the block recursive work of Menzio and Shi [2011] and Menzio et al. [2012] and on the matching models of Shimer and Smith [2000], Shi [2001], Moscarini [2001], Shimer [2001], Teulings and Gautier [2004], Bagger and Lentz [2008], Eeckhout and Kircher [2011], Hagedorn et al. [2012], Lise and Robin [2013], Bagger et al. [2014], and Eeckhout and Sepahsalari [2014] by allowing for credit constraints and sorting in a general equilibrium model of labor markets. Several studies including Lentz [2009], Krusell et al. [2010] and Nakajima [2012a] have studied the impact of savings on labor market dynamics, while Guerrieri and Lorenzoni [2011] among others have looked at the role household borrowing constraints play in models with frictionless labor markets and found significant interactions.

Our work complements the theoretic body of research on static models of sorting under credit constraints (Fernandez and Gali [1999], Legros and Newman [2002], Strauss [2013]), as well as the dynamic marriage market models with sorting that include credit constraints (Fernández and Rogerson [2000] among others) and models that consider occupational choice under constraints (Moscarini and Vella [2008], Neumuller [2014], Gervais et al. [2014], and Dinlersoz et al. [2015]).

Our paper builds on the defaultable debt literature (Chatterjee et al. [2007], Livshits et al. [2007], Drozd and Nosal [2008]) by including idiosyncratic endogenous employment risk in debt pricing, and intersects a new growing structural literature on unemployment and unsecured credit (Herkenhoff [2013], Bethune et al. [2013], Athreya et al. [2014], Donaldson et al. [2014], Kehoe et al. [2014]). The fact that firms invest to determine their types in the model is related to concurrent work by Chade and Lindenlaub [2015] and addressed in theory by Bonhomme et al. [2014].[4] Our theoretical contribution is to build the first dynamic general equilibrium sorting model with incomplete debt markets.

The paper proceeds as follows. We first describe our conceptual framework in Section 2. Section 3 describes the data. Sections 4 and 5 contain our empirical results and Section 6

[4]The model features credit constraints among firms in the form of defaultable debt, which is most closely related to Petrosky-Nadeau and Wasmer [2013] in the search literature.

presents the model, Section 7 describes the model estimation and structural estimates of the duration elasticity, Section 8 conducts the main counterfactual exercise of tightening debt limits, and Section 9 concludes.

2 Job Finding and Unsecured Credit

The recent financial crisis and recession has drawn attention to how labor markets are affected by private consumption smoothing mechanisms such as home equity loans (Hurst and Stafford [2004]), default arrangements (Athreya and Simpson [2006], Han and Li [2007], Gordon [2011], Herkenhoff and Ohanian [2012], Herkenhoff [2012], Dobbie and Song [2013], Albanesi and Nosal [2014]), mortgage modifications (Mulligan [2008, 2012] and Herkenhoff and Ohanian [2011]), and other combinations of spousal labor supply and assets (Blundell et al. [2012] and citations therein).

We continue this renewed focus by examining how unsecured credit and access to home equity lines of credit affect individuals losing their jobs after large displacements. Conceptually, the idea is that individuals may be able to use personal resources including unsecured credit in order to maintain consumption while searching for a job. Individuals who have suffered a job loss can use unsecured credit to continue to pay their bills and consumption while unemployed and thus those individuals with higher unsecured credit may be able to search longer and find a better job.

While this idea is relatively straight forward, the role of unsecured credit in unemployed households' job finding decisions is actively debated in the profession.[5] A common limitation of existing empirical studies is a lack of information on credit limits which can be used to self-insure against unemployment and used to smooth and maintain consumption.[6] As a result, many studies in this area are constrained to operate under the assumption that credit markets only impact individuals if they borrow and draw down their credit lines.

Theory suggests that what actually matters to households to offset job loss and income shocks is the stock of resources available to the household, which is the unused credit plus liquid assets (see Carroll et al. [2012] and citations therein). Using our linked employee-personal credit data we are able to address how households can use credit lines as a self-insurance device. Credit lines can act as self-insurance devices, even if never drawn upon, and therefore, unused credit limits (a measure of resources on hand), are better measures

[5]See Athreya et al. [2009], Nakajima and Ríos-Rull [2014], and Bethune [2015] have shown quantitatively that unsecured credit markets do not mitigate consumption volatility. Others such as Hurst and Stafford [2004], Herkenhoff [2013], Albanesi and Nosal [2014], and Gelman et al. [2015] have found empirical evidence consistent with models such as Herkenhoff and Ohanian [2012] in which unemployed households use credit markets in various ways to smooth consumption. We attempt to reconcile these two views in the literature.

[6]Survey data lack accurate credit limit data and are often times limited to low-frequency panels with less than 200 involuntary unemployment spells or cross-sections with no prior-balance information (such as the SCF).

of ability to self-insure than realized borrowing. Since nearly every household (and nearly every unemployed household) in the US has some form of credit access, we build a model that can be used to measure the affect of unsecured credit on the macroeconomy.[7] In our model, households with large limits who never draw down their lines of credit will have more resources on hand and take longer to find jobs.

Based on these theoretic predictions, in the following empirical sections, we test two hypotheses:

Hypothesis 1: Ceteris paribus, greater credit access among the unemployed increases non-employment durations.

Hypothesis 2: Ceteris paribus, greater credit access among the unemployed increases subsequent re-employment earnings.

The answers to these two hypotheses are important for both the empirical and theoretical debate regarding the role unsecured credit plays in both consumption smoothing and job search behavior.

3 Data and Definitions

We use a randomly drawn panel of 5 million individuals from TransUnion credit reporting agency that we link to the Longitudinal Employment and Household Dynamics (LEHD) data to examine job finding and unemployement durations data. All consumer credit information is taken from TransUnion at an annual frequency from 2001 to 2012. TransUnion is one of the three largest credit scoring companies in the United States, and it has a similar market share to Equifax and Experian. Our main sample is a 5% random sample of individuals with credit reports from the 11 states for which we have LEHD data. The TransUnion data is then merged based on social security numbers to the LEHD. The TransUnion data includes information on the balance, limit, and status (delinquent, current, etc.) of different classes of accounts held by individuals. The different types of accounts include unsecured credit as well as secured credit on mortgages.

We link this consumer credit data to the LEHD quarterly earnings and employee characteristic database. The LEHD database is a matched employer-employee dataset that covers 95% of U.S. private sector jobs. We follow Abowd et al. [2009] (Appendix A, Definitions of Fundamental LEHD Concepts) to construct our measures of job accessions and employment at end-of-quarter. Our earnings data span from 1995 to 2008 for 11 states: California, Maryland, Illinois, Texas, Indiana, Nevada, New Jersey, Oregon, Rhode Island, Virginia, and Washington.

To mitigate concerns of unobserved heterogeneity among job losers, we follow Jacobson

[7]See Herkenhoff [2013]'s online appendix for credit access measures among the unemployed.

et al. [1993] and focus on mass layoffs. We combine data from the Longitudinal Business Dynamics (LBD) database on establishment exits with the LEHD. In each state, employers are assigned a State Employment Identification Number (SEIN) in the LEHD database. This is our unit of analysis for mass layoffs. We define a mass layoff to occur when an SEIN with at least 25 employees reduces its employment by 30% or more within a quarter and continues operations, or exits in the LEHD. To ensure that the there was actually a mass layoff, we then verify that fewer than 35% of workers move to any other single SEIN. This removes mergers, firm name-changes, and spin-offs from our sample. We further limit ourselves to workers with at least 3 years of tenure, following Davis and Von Wachter [2011], to mitigate any issues associated with seasonal employment or weak labor-force attachment.

Non-employment duration is defined in quarters and takes values ranging from 0 (indicating immediate job finding) to 9 (all spells longer than 9 quarters of non-employment are assigned a value of 9).[8] Suppose a worker is displaced in year t, then we define the replacement earnings ratio to be the ratio of annual earnings in the year after layoff, in year $t+1$, (including zeros) to the pre-displacement annual earnings, in year $t-1$. Our results are robust to dropping those with zero earnings in year $t+1$ or measuring the replacement earnings 2 years after layoff, in year $t+2$, with or without zeros.[9]

4 Empirical Approach

We estimate the impact of credit access on non-employment durations among displaced workers and the quality of the subsequent jobs they take.[10] Our main measure of credit access is the unused credit limit across all types of revolving debt (excluding any mortgage related revolving debt) over annual earnings (hereafter, 'unused revolving credit limit ratio').[11] The unused credit limit and annual earnings are both measured prior to displacement.[12] Re-

[8]Very few households in our sample of displaced workers remain non-employed for longer than 4 quarters. Since we only observe employment histories through 2008, about 5% of observations in the 2007 layoff cohort are censored. Our results are insensitive to the inclusion of this cohort.

[9]We not do report results for which we drop 0s for disclosure purposes since it results in small subsamples, but we note that the coefficients are larger and more significant if we do so. Likewise, we do not report results for which we consider earnings losses 2 years after layoff for disclosure purposes since lose one cohort's worth of observations, but we note that the sign, significance, and magnitude of the coefficients are very similar.

[10]Since we do not see UI uptake, and since we do not actually observe the workers state of mind, we cannot classify households as unemployed.

[11]In the main text, to control for housing wealth, we will control directly for HELOCs and mortgage credit. The results are very similar if we instrument revolving credit including HELOCs, or total credit including HELOCs, which is shown in Appendix B.2.

[12]The standard measure of credit limits in this paper corresponds to the TransUnion variable 'Revolving High Credit/Credit Limit.' This variable is constructed as the sum of the 'High Credit/Credit Limit' across all types of revolving debt. The 'High Credit/Credit Limit' is defined as the actual credit limit if such a limit is recorded or the highest historical balance if no credit limit is recorded. We then subtract the total

volving credit is primarily composed of bank revolving (bank credit cards), retail revolving (retail credit cards), and finance revolving credit (other personal finance loans with a revolving feature). Revolving credit is most likely to impact the unemployed as it can be drawn down on short notice and paid-off slowly over time without any additional loan-applications or income-checks.

While most of the literature including Jacobson et al. [1993] have argued that mass layoffs are exogenous to worker characteristics, credit access upon layoff certainly is not. The goal is to find a characteristic of households that impacts credit limits and only impacts employment prospects through its impact on credit limits. To isolate such exogenous variation in credit limits, we follow Saiz [2010] and Mian and Sufi [2012] who exploit variation in geography to answer a wide variety of questions (in Appendix B.1 we use the Gross and Souleles [2002] instrument for robustness). Our main approach is to instrument the unused credit limit ratio of households with the geographic constraints of the MSA in which the household lives, and then use this exogenous component of unused credit limits to measure the impact of credit on various employment outcomes such as job finding rates and earnings replacement rates.

Mian and Sufi [2012] have laid much of the groundwork for this instrument by showing that geographic constraints significantly impact house price growth as well as leverage and are orthogonal to labor markets except through their impact on leverage (their samples always exclude construction workers and real-estate related sectors). Our analysis relies on the arguments made in Mian and Sufi [2012], but, rather than focusing on *realized leverage* (realized borrowing), the channel we emphasize is that geographic constraints impact house price growth, and house price growth is a determinant of *credit access*, and in particular, credit limits. There are two reasons why house prices determine access to revolving credit: (i) households have more access to capital and are less likely to default, increasing the propensity of lenders to extend any type of credit, and (ii) lenders expect households to consume more, and therefore offer more credit cards since they profit from transaction volume (not just balances). In the first-stage regression, we show that the Saiz [2010] geographic constraint instrument is a strong predictor of the unused credit limit ratio of individual households for the 38 MSAs present in our sample. In the second stage regression, the predicted unused credit limit ratios from the first stage are used to measure the impact of credit on non-employment durations and annual earnings replacement rates.

Consider the sample of households laid-off due to plant closure in year t. Let $D_{i,t}$ denote the non-employment duration (in quarters and capped at 9 quarters) of individual i who is laid off in year t. Let $l_{i,t-1}$ denote the unused limit ratio of individual i in year $t-1$, the year prior to layoff.[13] Let $X_{i,t}$ include static demographic controls as well as state-level aggregate economic controls. We estimate the following linear model of non-employment durations:

current revolving credit balance to arrive at unused credit limit.

[13]Due to the frequency of the credit reports, we use annual credit limit information. Likewise, the earnings information is annual earnings. Durations of non-employment are measured in quarters.

$$D_{i,t} = \gamma l_{i,t-1} + \beta X_{i,t} + \epsilon_{i,t}$$

Our coefficient of interest is γ, which is the impact of unused credit limits on non-employment durations, *ceteris paribus*. As discussed above, unused credit limits $l_{i,t-1}$ are endogenous. Simultaneity bias is particularly worrisome. Employment prospects tomorrow determine credit limits, and credit limits determine employment prospects via their impact on the households ability to self-insure. To circumvent this endogeneity, we use an instrumental variables approach where our instrument is the housing supply elasticity for the MSA in which the household lives.

Let $s_{i,t}$ denote the housing supply elasticity of the MSA for which individual i lives at date t. The first-stage regression is to predict the unused credit limit ratio as a function of the housing supply elasticity.

$$l_{i,t-1} = \pi s_{i,t} + B X_{i,t} + u_{i,t}$$

These first-stage estimates of π and B are used to isolate the exogenous component of the unused credit limit ratio, $\hat{l}_{i,t-1}$. The second stage regression is then used to estimate how this exogenous variation in credit impacts employment outcomes.

$$D_{i,t} = \gamma \hat{l}_{i,t-1} + \beta X_{i,t} + \epsilon_{i,t}$$

4.1 Sample

Our sample includes displaced households with mortgages who had at least 3 years of tenure at the time of displacement who worked in a non-construction or non-real-estate industry, and worked at a firm with at least 25 employees. Given these criteria we end up with a sample (to the nearest thousand) of 19,000.[14] Given the way we identify displacements, and the use of lagged credit prior to displacement, our sample covers the years 2002-2007. All variables are deflated by the CPI. When we estimate the model, our vector of controls ($X_{i,t}$) includes a quadratic in age, sex, education dummies, lagged annual income, cumulative lagged earnings (to proxy for assets), a quadratic in tenure, 1-digit SIC industry dummies, a dummy for the presence of auto loans, an equity proxy (in one set of specifications), HELOC limits (in one set of specifications), as well as year dummies and the MSA unemployment rate, and MSA income per capita.

[14]Census requires sample numbers to be rounded off to the nearest hundred to ensure no individual data is disclosed or can be inferred. We round to the nearest thousand to allow for quicker disclosure of results. The final version will be rounded to the nearest hundred.

4.2 Descriptive Statistics and Raw Correlations

Table 1 includes summary statistics for the sample of homeowners used in the empirical analysis. On average households in our sample are roughly 43 years old and have worked at their prior job for about 6 years before the mass layoff. On average, their annual labor earnings were about $57,000 prior to layoff. Households can replace on average 50% of their prior annual labor earnings with unused revolving credit.[15] As mentioned above, revolving credit is primarily composed of bank revolving (bank credit cards), retail revolving (retail credit cards), and finance revolving credit (other personal finance loans with a revolving feature). Households involved in mass displacements take roughly 1.65 quarters to find a new job. Annual earnings replacement rates are 79% one year after mass displacement, similar to what Davis and Von Wachter [2011] find. Finally, the age of the oldest tradeline (any type of credit line) is approximately 14 years on average in our sample.

Table 1: Summary Statistics (Source: LEHD/TransUnion)

Variable	**Mean**
Age	43.06
Tenure	5.80
Imputed Years of Education	13.75
Lagged Annual Earnings	$57,245
Lagged Revolving Unused Credit to Income	0.52
Lagged Total Credit to Unused Income	0.87
Duration of Non-Employment (Quarters)	1.65
Replacement Rate (Annual Earnings Year t+1/Annual Earnings Year t-1)	0.79
Lagged Months Since Oldest Tradeline Opened	178.60
Observations (Rounded to 000s)	19000

Notes. Sample includes displaced households with mortgages who had at least 3 years of tenure at the time of displacement who worked in a non-construction or non-real-estate industry, and worked at a firm with at least 25 employees.

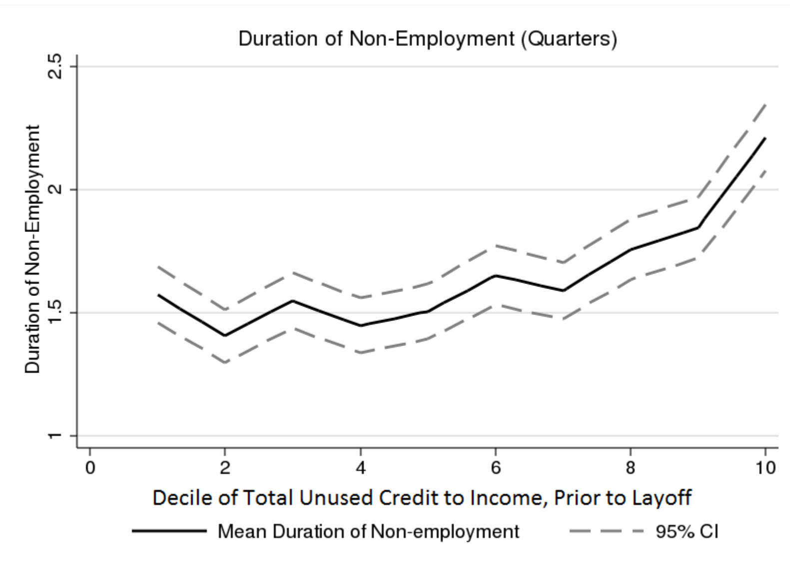
Figures 1 and 2 plot the duration of non-employment and replacement rate, respectively, by unused revolving credit to income decile, *prior to layoff*. The deciles of unused revolving

[15] The distribution of replacement rates is positively skewed. In the SCF, *unused credit card limits* to annual *family* income among the unemployed peaks at 38% in 1998, and among the employed it peaks at 33% in 2007.

credit to income range from approximately zero to roughly 200%. In other words, those in the top decile can approximately replace 2x their annual income with revolving credit.

Duration is generally monotone increasing in unused credit, increasing by about .75 quarters from the lowest unused credit to income decile to the highest. The replacement rate is initially falling and then increasing sharply in the top two credit deciles. The inclusion of zeros in the replacement rate graph as well as composition effects generate much of the non-linearity seen in Figure 2, and dropping zeros yields a much more monotone figure. The following empirical exercises will remove the composition effects and draw causal inference about the relationships seen in Figures 1 and 2.

Figure 1: Non-Employment Duration by Unused Revolving Credit to Income Decile, *prior to layoff* (Source: LEHD/TransUnion)

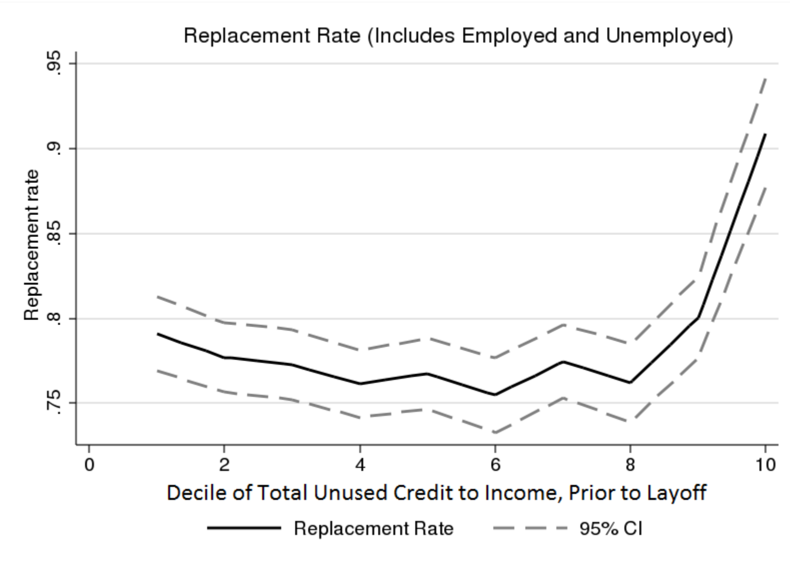


5 Empirical Results

Table 2 illustrates our results when considering the Saiz [2010] house supply elasticity measure. We estimate the model using two-stage least squares with clustered standard errors at the MSA level denoted in parentheses.

Column (1) reports the impact of the unused credit limit ratio on non-employment durations in quarters. The coefficient can be interpreted as follows: being able to replace 10% more of prior annual earnings with unused credit increases the duration of non-employment

Figure 2: Replacement Earnings 1 Year After Layoff (Including 0s) by Unused Revolving Credit to Income Decile, *prior to layoff* (Source: LEHD/TransUnion)



by .08 quarters, or roughly 1 week. Column (2) reports the impact of unused credit on the replacement rate of annual earnings for a household, 1 year after displacement. A 10% increase in the unused credit limit ratio increases the replacement rate of earnings 1 year after layoff by 1.34%.

Column (3) reports the impact of the unused credit limit ratio on the probability that a worker finds a job at a firm in the 99th percentile of the firm size distribution ('Large Firm Dummy'), measured 1 year after displacement.[16] A 10% increase in the unused credit limit ratio increases the probability a worker works at a large firm 1 year after layoff by 2.4%. Column (4) reports the impact of the unused credit ratio on the probability that a worker finds a job at a firm in the 75th percentile of the age distribution ('Old Firm Dummy'), measured 1 year after displacement. A 10% increase in the unused credit limit ratio increases the probability a worker works at an old firm 1 year after layoff by 3.14%.

Table 3 provides the same analysis using the Wharton Land Regulation Index (WRI) as an instrument for credit constraints. In general the Wharton Land Regulation Index is negatively correlated with the housing supply elasticity with a correlation of -.59. Column (1) reports the impact of unused credit on non-employment durations. In this specification, the ability to replace 10% more of annual income using revolving credit increases the duration

[16] What we call firms in the text are SEINs in the LEHD, where SEINs only aggregates all plants within a state. Firms (SEINs) in the 99th percentile of the size distribution comprise approximately 1/3 of employment. Firms (SEINs) in the 75th percentile of the age distribution comprise approximately 1/3 of employment. The deciles of firm (SEIN) size and age are measured within each state for each year, across all SEIN's present in the LEHD.

Table 2: Instrument is Saiz House Supply Elasticity, IV OLS. Col. 1 Dependent Variable is Duration (in Quarters), Col. 2 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Col. 3 Dependent Variable is Dummy of 99th Pctile of Firm Size Distribution, 1 year after layoff. Col. 4 Dependent Variable is Dummy of 75th Pctile of Firm Age Distribution, 1 year after layoff. (Source: 2002-2007 LEHD/TransUnion)

Dep. Var	(1) Duration	(2) Replacement Rate	(3) Large Firm Dummy	(4) Old Firm Dummy
Revolving Unused Credit to Income	0.800***	0.134**	0.240***	0.314**
	(0.284)	(0.0670)	(0.0719)	(0.143)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	Y	Y	Y	Y
R2 First Stage	0.0529	0.0529	0.0529	0.0529
Angrist Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets.*

of non-employment by .1 quarters, or 1.2 weeks. Column (2) reports the impact of unused credit on the replacement rate of annual earnings. The ability to replace 10% more of annual income using revolving credit increases the replacement rate by 1.63%. Column (3) reports the impact of the unused credit limit ratio on the probability that a worker finds a job at a firm in the 99th percentile of size ('Large Firm Dummy'), measured 1 year after displacement. A 10% increase in the unused credit limit ratio increases the probability a worker works at a large firm 1 year after layoff by .636%, but this point estimate is insignificant. Column (4) reports the impact of the unused credit ratio on the probability that a worker finds a job at a firm in the 75th percentile of age ('Old Firm Dummy'), measured 1 year after displacement. A 10% increase in the unused credit limit ratio increases the probability a worker works at an old firm 1 year after layoff by 1.54%, but this point estimate is also insignificant.

Table 3: Instrument is Wharton Land Regulation Index, IV OLS. Col. 1 Dependent Variable is Duration (in Quarters), Col. 2 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Col. 3 Dependent Variable is Dummy of 99th Pctile of Firm Size Distribution, 1 year after layoff. Col. 4 Dependent Variable is Dummy of 75th Pctile of Firm Age Distribution, 1 year after layoff. (Source: 2002-2007 LEHD/Transunion)

	(1) Duration	(2) Replacement Rate	(3) Large Firm Dummy	(4) Old Firm Dummy
Revolving Unused Credit to Income	1.090***	0.163*	0.0636	0.154
	(0.327)	(0.0862)	(0.158)	(0.157)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	Y	Y	Y	Y
R2 First Stage	0.0522	0.0522	0.0522	0.0522
Angrist Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets.*

5.1 Discussion of Identifying Assumptions, Housing Wealth, and Aggregate Conditions

The argument made and supported by Mian and Sufi [2012] is that the housing supply elasticity impacts leverage, and only through leverage, does it impact employment. The identifying assumptions in the present study are $E[l_{i,t-1}s_{i,t}] \neq 0$ and $E[\hat{l}_{i,t-1}\epsilon_{i,t}] = 0$. The first condition, relevance, is straight-forward to establish.[17] The second condition, exogeneity, justifies additional discussion. From a purely statistical standpoint, we show below in Tables 5 and 7, using the square of the housing supply elasticity and the square of the WRI to achieve over-identification, that the instruments, in all but one case, pass the J-test (this is, however, only a specification test). We elaborate on these results in more detail below.

There are two further challenges to validity that warrant discussion, (i) aggregate conditions, and (ii) housing wealth. We conduct a thought experiment to address the first challenge. While Mian and Sufi [2012] argue that there is no correlation between the supply elasticity and aggregate conditions except through leverage, if there is a correlation, it should bias our results toward zero. Suppose MSAs with low supply elasticities have quickly rising house prices and have better labor markets, then credit should expand and non-employment durations should be shorter in those MSAs. This is the exact opposite of what our IV estimates reveal.

To mitigate concerns about housing wealth, we include an equity proxy (the highest mortgage balance ever observed less the current balance) and HELOC limits (home equity lines of credit) in our regressions, and we directly control for house prices in Appendix B.4. When trying to capture wealth effects coming from house price appreciation, HELOC limits isolate the relevant portion of housing wealth for job loss episodes. HELOC limits indicate what portion of the home can be used as an ATM immediately following a job loss. We argue that the HELOC credit limit just prior to a job loss is a good proxy for access to liquid assets of households. The idea is that whether the house is worth 200k or 220k should not affect short term job search decisions directly. Only if the job loser can use the equity of the home to smooth consumption, should the value of the home impact short term job search decisions.

One may argue that price appreciation, whether or not it is reflected in home equity limits, may change job search decisions because displaced workers can always sell their home. Less than 10% of households in our final sample do so around displacement, and if we drop interstate movers, our results remain unchanged. Since the average job loss spell in our data is quite short, it is unlikely that a household who is laid off will be able to secure additional home equity lines, or vacate the home immediately and sell the house. As Piazzesi et al. [2015] show empirically, it takes over 1 quarter for the median homeowner to sell their home, once it is listed.[18]

As explained above, to directly address these housing wealth concerns, Table 4 estimates the impact of unused credit on durations and replacement earnings using the housing supply

[17] We include both the Stock-Yogo and Angrist-Pischke Fstat tests to test whether the endogenous regressors are weakly identified. In every specification we can reject weak identification for the supply elasticity and the WRI. The square of the housing supply elasticity and WRI are very strong instruments.

[18] Intuition would lead one to believe that it would be at least a few months for the laid off worker to realize that employment prospects are poor, another month or so to move his family from the home/find a new place, and another quarter to sell the house (and likely rental rates are higher, mitigating wealth effects).

elasticity as an instrument, but we include additional controls: (i) an equity proxy (the highest mortgage balance observed less the current balance), and (ii) the summed limit of all home equity lines of credit (HELOCs). Columns (1) through (4) of Table 4 illustrate the persistence of the main results, even as we progressively add more controls for home equity and assets. The point estimate in Column (4) of .824 still implies that being able to replace 10% of prior annual earnings with unused revolving credit allows workers to take about 1 week longer to find a job. Columns (5) through (8) repeat the same exercise using replacement rates as the dependent variable instead. Again, we see that the point estimates actually strengthen with the inclusion of home equity proxies, with a 10% increase in revolving credit to income prior to layoff leading to a 1.5% greater earnings outcome 1 year later.

We conduct the same exercise in Table 6, adding housing equity controls to the IV regressions based on the Wharton Land Regulation Index (WRI). Columns (1) through (4) produce similar results in terms of duration when compared to Table 3, and Columns (5) through (8) also produce similar results in terms of replacement rates when compared to Table 3.

To further explore the role of house prices, in Appendix B.4, we conduct OLS regressions of duration on unused credit, directly controlling for the OFHEO house price index. Our instrument operates through house prices, and so treating house prices as an exogenous control in the IV specification, when in fact it is itself endogenous, would invalidate our identification strategy. We show the OLS estimates for completeness, but these results should be interpreted as correlations only. We find that the raw correlation between unused credit and the duration of non-employment among displaced workers is both significant, and positive, and it is not impacted by the inclusion of the house price index in the OLS regression. The same is true for replacement earnings: the correlation between replacement earnings and unused credit is significant and positive, and it is unchanged by the inclusion of a house price index in the OLS regression.

We turn to the Survey of Consumer Finances (SCF) to address concerns about the portfolio of liquid assets, housing wealth, and non-housing wealth. In Appendix B.3, we conduct OLS regressions of non-employment duration on various components of wealth for the 2007 SCF. We show that the relationship between non-employment duration and unused credit card limits (the only limits available in the SCF) is positive, significant, and of similar magnitude to what we find in the LEHD/TransUnion dataset. Moreover, this result is not impacted by the inclusion of home equity proxies or controlling for other liquid and illiquid assets.

In terms of direct tests of exogeneity, there are none. But Tables 5 and 7 use the square of the housing supply elasticity and the square of the WRI, respectively, to achieve over-identification. We conduct J-tests in which the null hypothesis is that the instrument is valid. Large p-values indicate failure to reject the null, and in all cases, except for the regression of replacement rates using supply elasticity as an IV, the instruments pass the J-test. In particular, Table 5 includes over-identification tests for the housing supply elasticity, and the only time the instrument fails the J-test is in the replacement earnings regressions. As Mian and Sufi [2012] show, in several of their county regressions, the housing supply elasticity is related to BLS measures of wages. On the other hand, Table 7 shows that the Wharton Land Regulation Index passes each of the J-tests quite easily. In no cases can we reject the null that the WRI is a valid instrument. For this reason, the WRI is our preferred instrument.

5.2 Additional Robustness, Gross and Souleles (2002) Instrument

In Appendix B, we also use the Gross and Souleles [2002] instrument. Their strategy was to use automatic limit increases as an instrument for credit limits. We conduct a similar analysis, using account ages, conditional on age and income, as an alternate instrument for credit limits. Using the Gross and Souleles [2002] instrument, we find similar signs and significance levels for the impact of unused credit on duration and replacement rates. We find that being able to replace 10% of prior annual earnings with revolving credit allows displaced workers to take $\frac{1}{3}$ of one week longer to find a job. Likewise, being able to replace 10% of prior annual earnings with revolving credit is associated with .6% greater earnings replacement rate, 1 year after layoff.

5.3 Relation to Unemployment Insurance Estimates

In the Unemployment Insurance (UI) literature, several papers including Katz and Meyer [1990], Meyer [1991], Chetty [2008], Rothstein [2011], Hagedorn et al. [2013], and Card et al. [2015] have measured the impact of unemployment benefits (replacement rates and length) on job finding rates, and Addison and Blackburn [2000] (see citations therein) have considered the impact of unemployment benefits on re-employment earnings, finding significant but mixed-magnitude effects in US data. While these UI estimates can be used as a litmus test of our empirical results, the self-insurance properties of credit differ from unemployment insurance for several reasons: (i) credit lines can be drawn down before an unemployment spell begins, producing strong offsetting effects on job finding behavior (see Herkenhoff [2013]), (ii) credit lines are supposed to be repaid and interest rates are idiosyncratic which has the potential to change what type of wages workers search for, (iii) informal bankruptcy and formal bankruptcy provide workers with alternate forms of self-insurance that may be more valuable in downturns when credit is scarce, (iv) monetary policy disproportionately impacts credit carrying households, (v) many more unemployed households carry credit cards than claim unemployment benefits.

Our estimates imply that 1$ of additional unused credit limit is about one-fourth to one-half as potent for both durations and replacement earnings as 1$ of unemployment benefit. Being able to replace 5% of annual earnings on a credit card is equivalent to a 10% increase in UI replacement rates for the typical 6-month unemployment duration. Most estimates of impact of a 10% increase in the replacement rate is to increase non-employment durations

Table 4: Instrument is Housing Supply Elasticity. Includes Housing Equity Proxies. Cols. 1 to 4 Dependent Variable is Duration (in Quarters). Cols. 5 to 8 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Cols. Progressively Adds Home Equity Proxies.

Dep. Var.	(1) Duration	(2) Duration	(3) Duration	(4) Duration
Revolving Unused Credit Limit to Income	0.800***	0.801***	0.839**	0.824***
	(0.284)	(0.275)	(0.329)	(0.311)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0529	0.0533	0.0569	0.0578
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

Dep. Var.	(5) Replacement Rate	(6) Replacement Rate	(7) Replacement Rate	(8) Replacement Rate
Revolving Unused Credit Limit to Income	0.134**	0.127**	0.145*	0.150**
	(0.0670)	(0.0633)	(0.0751)	(0.0749)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0529	0.0533	0.0569	0.0578
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets. Equity proxy is highest observed mortgage balance less current balance. HELOC limits is sum of all home equity line of credit limits.*

Table 5: Overidentification Tests. Instrument is Housing Supply Elasticity and Housing Supply Elasticity Squared. Includes Housing Equity Proxies. Cols. 1 to 4 Dependent Variable is Duration (in Quarters). Cols. 5 to 8 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Cols. Progressively Adds Home Equity Proxies.

Dep. Var.	(1) Duration	(2) Duration	(3) Duration	(4) Duration
Revolving Unused Credit Limit to Income	0.835** (0.337)	0.830** (0.327)	0.876** (0.389)	0.863** (0.371)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0536	0.0540	0.0573	0.0583
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000
Pval J test Null Valid	0.700	0.742	0.716	0.684

Dep. Var.	(5) Replacement Rate	(6) Replacement Rate	(7) Replacement Rate	(8) Replacement Rate
Revolving Unused Credit Limit to Income	0.0880 (0.0666)	0.0856 (0.0625)	0.0990 (0.0750)	0.102 (0.0751)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0536	0.0540	0.0573	0.0583
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000
Pval J test Null Valid	0.00642	0.0127	0.0146	0.00770

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets. Equity proxy is highest observed mortgage balance less current balance. HELOC limits is sum of all home equity line of credit limits.*

Table 6: Instrument is Wharton Land Regulation Index. Includes Housing Equity Proxies. Cols. 1 to 4 Dependent Variable is Duration (in Quarters). Cols. 5 to 8 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Cols. Progressively Adds Home Equity Proxies.

Dep. Var.	(1) Duration	(2) Duration	(3) Duration	(4) Duration
Revolving Unused Credit Limit to Income	1.090***	1.099***	1.188***	1.151***
	(0.327)	(0.315)	(0.378)	(0.364)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0522	0.0524	0.0563	0.0571
Angirst Pischke FStat Pval	0	0	1.13e-09	3.26e-10
Pval Weak Id Null Weak	0	0	1.12e-09	3.22e-10
Round N	19000	19000	19000	19000

Dep. Var.	(5) Replacement Rate	(6) Replacement Rate	(7) Replacement Rate	(8) Replacement Rate
Revolving Unused Credit Limit to Income	0.163*	0.148*	0.168*	0.183*
	(0.0862)	(0.0831)	(0.0979)	(0.0980)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0522	0.0524	0.0563	0.0571
Angirst Pischke FStat Pval	0	0	1.13e-09	3.26e-10
Pval Weak Id Null Weak	0	0	1.12e-09	3.22e-10
Round N	19000	19000	19000	19000

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets. Equity proxy is highest observed mortgage balance less current balance. HELOC limits is sum of all home equity line of credit limits.*

Table 7: Overidentification Tests. Instrument is Wharton Land Regulation Index (WRI) and WRI Squared. Includes Housing Equity Proxies. Cols. 1 to 4 Dependent Variable is Duration (in Quarters). Cols. 5 to 8 Dependent Variable is Replacement Earnings, 1 Year After Layoff. Cols. Progressively Adds Home Equity Proxies.

	(1)	(2)	(3)	(4)
Dep. Var.	Duration	Duration	Duration	Duration
Revolving Unused Credit Limit to Income	1.148***	1.150***	1.251***	1.218***
	(0.337)	(0.330)	(0.390)	(0.374)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0527	0.0530	0.0567	0.0575
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000
Pval J test Null Valid	0.633	0.682	0.656	0.618

	(5)	(6)	(7)	(8)
Dep. Var.	Replacement Rate	Replacement Rate	Replacement Rate	Replacement Rate
Revolving Unused Credit Limit to Income	0.160**	0.150**	0.171**	0.181**
	(0.0729)	(0.0709)	(0.0836)	(0.0821)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0527	0.0530	0.0567	0.0575
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000
Pval J test Null Valid	0.866	0.951	0.908	0.910

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets. Equity proxy is highest observed mortgage balance less current balance. HELOC limits is sum of all home equity line of credit limits.*

by .3 to 2 weeks with the modal estimate lying between .5 and 1 for the US (see Nakajima [2012b] for a summary of both empirical and quantitative elasticities). Our estimates imply an equivalent elasticity of .15 to .3 weeks– the low end of UI estimates and about half of what Card et al. [2015] find using state-of-the-art estimation techniques.

6 Model

To understand how fluctuations in credit constraints impact the macroeconomy, we build a model that is capable of replicating the facts shown above, and then we conduct several experiments: our main experiment is to consider how changes to the borrowing limit subsequently impact employment, output, and productivity recoveries.[19] Let $t = 0, 1, 2, \dots$ denote time. Time is discrete and runs forever. There are three types of agents in this economy. A unit measure of risk averse finitely-lived households, a continuum of risk neutral entrepreneurs that run the endogenously chosen measure of operating firms, and a unit measure of risk neutral lenders.

As in Menzio et al. [2012], there are $T \geq 2$ overlapping generations of risk averse households that face both idiosyncratic and aggregate risk. Each household lives T periods deterministically and discounts the future at a constant rate $\beta \in (0, 1)$. Every period households first participate in an asset market where they make asset accumulation, borrowing, and bankruptcy decisions. After the asset market closes, households enter the labor market where they direct their search for jobs.[20] Let $c_{t,t+t_0}$ and $L_{t,t+t_0}$ respectively denote the consumption and hours worked of an agent born at date t in period $t + t_0$. The objective of a household is to maximize the expected lifetime flow utility from non-durable consumption and leisure.

$$\mathbb{E}_t \left[\sum_{t_0=1}^{T} \beta^{t_0} u(c_{t,t+t_0}, 1 - L_{t,t+t_0}) \right]$$

From this point on we will drop time subscripts and focus on a recursive representation of the problem. We assume that labor is indivisible, such that the household consumes its entire time endowment while employed $L = 1$, and vice verse for the unemployed.

Households are heterogeneous along several dimensions. Let $b \in \mathcal{B} \equiv [\underline{b}, \bar{b}] \subset \mathbb{R}$ denote the net asset position of the household, where $b > 0$ denotes that the households is saving, and $b < 0$ indicates that the household is borrowing. Let $h \in \mathcal{H} \subset \mathbb{R}_+$ denote the human capital of the worker. Workers also differ with respect to the capital $k \in \mathcal{K} \subset \mathbb{R}_+$ of the firm

[19] There are several recent search models with assets including Lentz and Tranaes [2001], Lentz [2009], Krusell et al. [2010], Nakajima [2012b], Eeckhout and Sepahsalari [2014], and Dinlersoz et al. [2015].

[20] The way directed search is modeled in this paper rules out the possibility that wage gains may simply reflect differences in bargaining power and outside options.

with which they are matched, and with respect to their credit access status $a \in \{G, B\}$ where $a = G$ denotes good standing, and $a = B$ denotes bad standing. Let $\mathbb{N}_T = \{1, 2, \dots, T\}$ denote the set of ages.

The aggregate state of the economy includes three components: (i) labor productivity $y \in \mathcal{Y} \subset \mathbb{R}_+$ and (ii) the borrowing limit $\underline{b} \subset \mathbb{R}_-$, and (iii) the distribution of agents across states $\mu : \{W, U\} \times \{G, B\} \times \mathcal{B} \times \mathcal{H} \times \mathcal{K} \times \mathbb{N}_T \to [0, 1]$. Let $\Omega = (y, \underline{b}, \mu) \in \mathcal{Y} \times \mathbb{R}_- \times M$ summarize the aggregate state of the economy where M is the set of distributions over the state of the economy. Let $\mu' = \Phi(\Omega, \underline{b}', y')$ be the law of motion for the distribution, and assume productivity and the borrowing limit follow a Markov process. It is important to note that even though there is an exogenously imposed borrowing limit $\underline{b}$, debt will be individually priced as in Chatterjee et al. [2007], and many workers will have 'effective borrowing limits' where the bond price reaches zero well before $\underline{b}$.

Let $M(u, v)$ denote the matching function, and define the labor market tightness to be the ratio of vacancies to unemployment. Since there is directed search, there will be a separate labor market tightness for each submarket. In each submarket, there is a job finding rate for households, $p(\cdot)$, that is a function of the labor market tightness $\theta_t(h, k; \Omega)$, such that $p(\theta_t(h, k; \Omega)) = \frac{M(u_t(h,k;\Omega), v_t(h,k;\Omega))}{u_t(h,k;\Omega)}$. On the other side of the market, the hiring rate for firms $p_f(\cdot)$ is also a function of the labor market tightness and is given by $p_f(\theta_t(h, k; \Omega)) = \frac{M(u_t(h,k;\Omega), v_t(h,k;\Omega))}{v_t(h,k;\Omega)}$. Once matched with a firm, a worker produces $f(y, h, k) : \mathcal{Y} \times \mathcal{H} \times \mathcal{K} \to \mathbb{R}_+$ and keeps a share α of this production.[21]

At the beginning of every period, households with debt positions $b < 0$ make a default decision. In the present formulation, the default punishment is similar to Ch. 7 bankruptcy in the United States.[22] A household in bankruptcy has a value function scripted by B and cannot save or borrow. With probability λ, a previously bankrupt agent regains credit access. If a household is in good standing (i.e. they have regained credit access), its value function is scripted with a G, and the household can freely save and borrow.

The problem of an unemployed household in good standing is given below. To suppress an additional state variable, we allow unemployment benefits $z(k)$ to be a function of the

[21] This a similar assumption to Kaplan and Menzio [2013], and is only made for tractability purposes. Directed search models with commitment to one submarket, including Shi [2001], find that firms optimally post unique wages that are monotone in workers' types, but other models in which firms do not commit to any given submarket, such as Shimer [2001], find non-monotone wages in workers' types within any given job, in some cases. Empirically, wage profiles are concave in education and decreasing for higher levels of education. We can allow for this by introducing flexible functional forms for production.

[22] Collateralized defaultable debt as in Luzzetti and Neumuller [2012] would reinforce the mechanism.

worker's prior wage, but only through its dependence on k.[23]

$$U_t^G(b,h,k;\Omega) = \max_{b' \geq \underline{b}} u(c,1) + \beta \mathbb{E}\Big[\max_{\tilde{k}} \; p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}(b',h',\tilde{k};\Omega') + \big(1 - p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}(b',h',k;\Omega')\Big], \quad t \leq T$$

$$U_{T+1}^G(b,h,k;\Omega) = 0$$

Such that

$$c + q_{U,t}(b',h,k;\Omega)b' \leq z(k) + b$$

We assume that human capital abides by the following law of motion (note that the process is indexed by employment status U):

$$h' = H(h,U)$$

And the shock processes and aggregate law of motion are taken as given:

$$y' \sim F(y' \mid y), \quad \underline{b}' \sim F(\underline{b}' \mid \underline{b}), \quad \mu' = \Phi(\Omega, y', \underline{b}'), \quad \Omega' = (y', \underline{b}', \mu') \tag{1}$$

For households who default, they are excluded from both saving and borrowing. There is an exogenous probability λ that they regain access to asset markets:

$$\begin{aligned} U_t^B(b,h,k;\Omega) = u(c,1) + \lambda\beta\mathbb{E}\Big[&\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}(0,h',\tilde{k};\Omega') \\ &+ \big(1 - p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}(0,h',k;\Omega')\Big] \\ + (1-\lambda)\beta\mathbb{E}\Big[&\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}^B(0,h',\tilde{k};\Omega') \\ &+ \big(1 - p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}^B(0,h',k;\Omega')\Big], \quad t \leq T \end{aligned}$$

$$U_{T+1}^B(b,h,k;\Omega) = 0$$

Such that

$$c \leq z(k)$$

and the law of motion for human capital and aggregates are taken as given.

For households in good standing, at the start of every period, they must make a default decision:

$$U_t(b,h,k;\Omega) = \max\Big\{U_t^G(b,h,k;\Omega), U_t^B(b,h,k;\Omega) - \chi\Big\}$$

Let $D_{U,t}(b,h,k;\Omega)$ denote the unemployed household's default decision. A utility penalty of default, χ, is necessary to support credit in equilibrium.

[23]Shocks to k during unemployment could proxy expiration of unemployment benefits.

A similar problem holds for the employed. The value functions are denoted with a W for employed households, and at the end of every period, employed households face layoff risk δ. If they are laid off, since the period is 1 quarter, we must allow the workers to search immediately for a new job.[24]

$$\begin{aligned} W_t^G(b,h,k;\Omega) = \max_{b' \geq \underline{b}} u(c,0) + \beta\mathbb{E}\Big[(1-\delta)W_{t+1}(b',h',k;\Omega') \\ +\delta\Big\{\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}(b',h',\tilde{k};\Omega') \\ + \big(1-p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}(b',h',k;\Omega')\Big\}\Big], \quad t \leq T \end{aligned}$$

$$W_{T+1}^G(b,h,k;\Omega) = 0$$

Such that the aggregate laws of motion are given by equation (1), human capital evolves according to the law of motion below,

$$h' = H(h,W)$$

and the budget constraint holds,

$$c + q_{W,t}(b',h,k;\Omega)b' \leq \alpha f(y,h,k) + b$$

The value functions for employed borrowers who default as well as the discrete default decision are formulated in an identical fashion to that of the unemployed.

$$\begin{aligned} W_t^B(b,h,k;\Omega) = u(c,0) + \lambda\beta\mathbb{E}\Big[(1-\delta)W_{t+1}(0,h',k;\Omega') \\ + \delta\Big\{\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}(0,h',\tilde{k};\Omega') \\ + \big(1-p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}(0,h',k;\Omega')\Big\}\Big] \\ + (1-\lambda)\beta\mathbb{E}\Big[(1-\delta)W_{t+1}^B(0,h',k;\Omega') \\ + \delta\Big\{\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}^B(0,h',\tilde{k};\Omega') \\ + \big(1-p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}^B(0,h',k;\Omega')\Big\}\Big], \quad t \leq T \end{aligned}$$

$$W_{T+1}^B(b,h,k;\Omega) = 0$$

[24]This allows the model to match labor flows in the data.

Such that the aggregate laws of motion are given by equation (1), human capital evolves such that $h' = H(h, W)$ and the budget constraint is given by,

$$c \leq \alpha f(y, h, k)$$

For employed households in good standing, at the start of every period, they must make the following default decision,

$$W_t(b, h, k; \Omega) = \max \left\{ W_t^G(b, h, k; \Omega), W_t^B(b, h, k; \Omega) - \chi \right\}$$

Let $D_{W,t}(b, h, k; \Omega)$ denote the employed household's default decision.

6.1 Lenders

There is a continuum of potential lenders who are risk neutral and can obtain funds, without constraint, at the risk free rate r_f. Lenders may lend to households or firms. Recall $e \in \{E, U\}$ denotes employment status. The price of debt for households must therefore satisfy the inequality below:

$$q_{e,t}(b', h, k; \Omega) \leq \frac{\mathbb{E}\Big[1 - D_{e',t}(b', h', k'; \Omega')\Big]}{1 + r_f} \tag{2}$$

Under free entry, the price of debt must yield exactly the risk free rate, r_f, and this equation holds with equality.

The price of debt for firms follows a similar form. For the sake of brevity, and the necessity for additional notation, this bond price will be shown below in the firm section. Since lenders, in equilibrium, earn zero profit for each contract, lenders are indifferent between lending to a firm or a household.

6.2 Firms

There is a continuum of risk neutral entrepreneurs that operate constant returns to scale production functions. The entrepreneurs invest in capital $k \in \mathcal{K} \subset \mathbb{R}_+$ and post vacancies to attract workers in the frictional labor market. We assume capital is denominated in units of the final consumption good.

The entrepreneur, when attempting to create a firm, is subject to a financing constraint. When a firm is not yet operational, the firm does not have access to perfect capital markets. The firm must borrow the money, $b_f < 0$ to finance the initial capital investment. If the firm fails to find an employee, the firm defaults and the capital is lost.[25]

[25] We are envisioning specific assets with low liquidation value, however, in one extension we allow for an explicit partial liquidation by the lender (capital is denoted in units of the final consumption good, and so this amounts to capital reversibility).

When deciding whether or not to post a vacancy, the firm solves the following problem. It chooses capital $k \in \mathcal{K}$ and what types of workers, indexed by human capital and age $(h,t) \in \mathcal{H} \times \mathbb{N}_T$, to hire. In the event that the worker is hired, the firm has access to perfect capital markets and repays b_f immediately. In the event that no worker can be found, the firm defaults. Let $J_t(h,k;\Omega)$ be the profit stream of a firm that has k units of physical capital and is matched with an age t worker with human capital h. Let $q_{f,t}(b,k,h;\Omega)$ denote the bond price faced by the firm. Then the problem a firm solves when attempting to recruit a worker is given below (recall b is negative if borrowing),

$$\kappa \leq \max_{k,h,t} p_f(\theta_t(h,k;\Omega))[J_t(h,k;\Omega) + b_f] + (1 - p_f(\theta_t(h,k;\Omega))) \cdot 0$$

such that

$$-k \geq q_{f,t}(b_f,k,h;\Omega) b_f$$

In equilibrium, this debt constraint holds with equality:

$$b_f = \frac{-k}{q_{f,t}(b_f,k,h;\Omega)}$$

With free entry in the lending market, the price of debt must be given by (note that k is implicitly related to b_f in the equation above),

$$q_{f,t}(b_f,k,h;\Omega) = \frac{p_f(\theta_t(h,k;\Omega))}{1 + r_f} \tag{3}$$

The amount borrowed by firms is given by,

$$b_f = (1 + r_f) \cdot \frac{-k}{p_f(\theta_t(h,k;\Omega))}$$

Because there is free entry among entrepreneurs, every submarket that is entered with positive probability must satisfy the following condition:

$$\kappa = p_f(\theta_t(h,k;\Omega)) \left[J_t(h,k;\Omega) - (1 + r_f) \cdot \frac{k}{p_f(\theta_t(h,k;\Omega))} \right]$$

Therefore, the market tightness in each market is given by,

$$\theta_t(h,k;\Omega) = p_f^{-1} \left(\frac{\kappa + (1 + r_f)k}{J_t(h,k;\Omega)} \right) \tag{4}$$

For tractability, we assume that workers and firms split output according to a constant piece-rate α. We assume the firm keeps a share $1 - \alpha$ of its production, and workers receive the remaining share α of production. Of that remaining output, firms must then pay a fixed cost f_c.[26] The value function for the firm is given by,

$$J_t(h,k;\Omega) = (1-\alpha)f(y,h,k) - f_c + \beta\mathbb{E}\big[(1-\delta)J_{t+1}(h',k;\Omega')\big], \qquad \forall t \leq T$$
$$J_{T+1}(h,k;\Omega) = 0$$

Under this constant-share output-splitting assumption (as well as invertibility conditions), from the worker's perspective, choosing among capital submarkets is equivalent to choosing among wage rates where the menu of wages is implicitly given by inverting the production with respect to capital $f^{-1}(y,h,\frac{w}{1-\alpha}) = k$.

6.3 Equilibrium

Let $\mathbf{x}$ summarize the state vector of a household. An equilibrium in this economy is a set of household policy functions for saving and borrowing $(\{b'_{e,t}(\mathbf{x})\}_{t=1}^{T})$, bankruptcy $(\{D_{e,t}(\mathbf{x})\}_{t=1}^{T})$, and a capital search choice $\{k_t(\mathbf{x})\}_{t=1}^{T}$, a debt price $(\{q_{e,t}(\mathbf{x})\}_{t=1}^{T})$ for both the employed ($e = W$) and unemployed ($e = U$), a debt price for firms $(\{q_{f,t}(\mathbf{x})\}_{t=1}^{T})$, a market tightness function $\theta_t(h,k;\Omega)$, processes for aggregate shocks $(y,\underline{b})$, and an aggregate law of motion $\Phi(\Omega,y',\underline{b}')$ such that

i. Given the law of motion for aggregates, the bond price, and market tightness function, households' decision rules are optimal.

ii. Given the law of motion for aggregates and the bond price, the free entry condition in the labor market (4) holds.

iii. Given household policy functions, the labor market tightness function, and the law of motion for aggregates, the free entry conditions for lenders making loans to households (2) and firms (3) both hold.

iv. The aggregate law of motion is consistent with household policy functions.

In what follows below, we use the same tools as Menzio and Shi [2011] to solve for a Block Recursive Equilibrium in which policy functions and prices do not depend on the aggregate distribution μ (even though it fluctuates over time and can be recovered by simulation). It is important to note that while the policy functions and prices do not depend on the distribution of agents across states, they still depend on the aggregate productivity of firms, y, and and the borrowing limit, $\underline{b}$. As we show below, a Block Recursive Equilibrium exists in this economy, and thus to solve the model economy, we only need to solve the first 'block' of the equilibrium i.-iii. ignoring iv., and then we can simulate to recover the dynamics of μ. Furthermore, we establish that certain classes of production functions yield uniqueness.

[26] The representative entrepreneur will make exactly zero profits across plants and over time, even if some firms are temporarily making negative profits. When calibrating the model this fixed cost will serve to generate a small surplus for firms, and help the model match quantitative features of the data.

6.4 Existence and Uniqueness

In this section, we show both existence and uniqueness of the equilibrium under various assumptions. The existence proof holds under mild conditions, but the uniqueness proof requires more stringent assumptions. We begin with Proposition 6.1 which is the existence result. Without loss of generality, we set the firm fixed cost f_c to zero.

Proposition 6.1. *Assume that the utility function meets standard conditions ($u' > 0, u'' < 0, \lim_{c \to 0} u'(c) = \infty, \lim_{c \to \infty} u'(c) = 0$, and u is invertible), the matching function is invertible and constant returns to scale, and there is a bounded support (which can be non-binding) for the choice set of debt $b \in \mathbb{B} \subseteq [\underline{b}, \overline{b}]$ and the capital of firms $k \in \mathcal{K} \subseteq [\underline{k}, \overline{k}]$, then a Block Recursive Equilibrium exists.*

Proof. Appendix C □

A simple corollary follows in which one can establish the existence of an equilibrium with debt.

Corollary 6.2. *Under the hypotheses of Proposition 6.1, so long as $\chi > 0$, and $\mathcal{B}$ contains a non-empty neighborhood of debt around 0, a Block Recursive Equilibrium with credit exists.*

Proof. Appendix C □

Now, we turn to uniqueness. One concern for uniqueness is the potential convexity of the problem. The reason why an equilibrium exists even without a cap on capital, and why potentially an unique equilibrium exists (under more stringent assumptions), crucially depends on the concavity of the production function with respect to k and the concavity of the matching function with respect to u and v. A strictly concave production function in k, $f_k > 0$, $f_{kk} < 0$ in conjunction with a strictly concave matching function (meaning strictly concave in u and v) will produce well defined, unique solutions.

What is the intuition behind this result? With a strictly concave production function, the matching rate will eventually asymptote to zero. This is because the benefit to the firm of buying more capital, k, declines due to the concavity of the production function, but the cost of an additional unit of k is weakly convex. Therefore an infinitely sized firm is never optimal with strict concavity in the production function. As a result, the vacancy to unemployment ($v/u = \theta$) ratio eventually declines to zero in k. Since the v/u ratio reaches zero for large values of k, households will look for jobs with finite k, and, with a properly chosen set of parameters, households will always restrict their choice to interior values of firm capital.

In Lemma (6.3) we provide sufficient conditions for the economy to admit a unique, Block Recursive Equilibrium.

Lemma 6.3. *In addition to the assumptions in Proposition 6.1, let the production function be Cobb-Douglas, i.e.* $f(y,h,k) = yh^{1-a}k^a$ $(0 < a < 1)$*, let the matching function be given by* $M(u,v) = u^{\frac{1}{2}}v^{\frac{1}{2}}$*, let* $\chi \to \infty$ *(no default for households), the value of leisure is zero, and assume there is no uncertainty over human capital* h*, aggregate productivity* y*, or the borrowing limit* $\underline{b}$*. Then if the utility function is negative, increasing, and concave (e.g.* $\frac{c^{1-\sigma}-1}{1-\sigma}$ *for* $\sigma > 1$ *or* $u(c) = -e^{-c}$*), the household labor search problem (equation (5)) admits a unique solution.*

Proof. Appendix C □

Why is Lemma 6.3 useful? For a broad range of production functions and utility functions, the model admits a unique solution, and so there is no equilibrium selection implicitly taking place in the computation below. Removing uncertainty in the proof is only for the sake of closed form solutions to the firm problem, and as long as the utility function of the household is additively separable in leisure, the proof holds.

7 Calibration

The parameters are calibrated so that the model's stochastic steady state is consistent with 1970-2007 averages. Stochastic steady state means that aggregate labor productivity (y) still fluctuates but that the borrowing limit ($\underline{b}$) is constant forever.[27] The period is set to one quarter. We calibrate the productivity process to match the Fernald et al. [2012], non-utilization adjusted total factor productivity series. The series is logged and band pass filtered to obtain deviations from trend with periods between 6 and 32 quarters. Aggregate productivity deviations are assumed to fluctuate over time according to an AR(1) process:

$$\ln(y') = \rho \ln(y) + \epsilon_1 \quad \text{s.t.} \quad \epsilon_1 \sim N(0, \sigma_e^2)$$

Estimation yields $\rho = 0.8934$ and $\sigma_e = 0.00548$, and the process is discretized using Rouwenhurst's method.

We set the annualized risk free rate to 4%. In stochastic steady state, we set $\underline{b} = -.5$, which is non-binding for all agents in our simulations. We set the job destruction rate to a constant 10% per quarter, $\delta = .1$ (Shimer [2005]). For the labor market matching function, we follow Haan et al. [1997] and use a constant returns to scale matching function that yields well-defined job finding probabilities:

$$M(u,v) = \frac{u \cdot v}{(u^\zeta + v^\zeta)^{1/\zeta}} \in [0, 1)$$

[27] A long sequence of productivity shocks is drawn according to the AR(1) process for y and large number of agents (N=30,000) is then simulated for a large number of periods (T=280 quarters, burning the first 100 quarters). Averages are reported over the remaining 180 quarters across $R = 10$ repetitions.

The matching elasticity parameter is chosen to be $\zeta = 1.6$ as in Schaal [2012].

Preferences are given below, where η is the flow from leisure, and L=1 for employed persons and L=0 otherwise:

$$u(c, 1-L) = \frac{c^{1-\sigma} - 1}{1-\sigma} + \eta(1-L)$$

We set the risk aversion parameter to a standard value, $\sigma = 2$. The life span is set to $T = 80$ quarters (20 years), and newly born agents are born unemployed, with zero assets, in good credit standing, and with a uniform draw over the grid of human capital. The household share of income, α, is set to $\frac{2}{3}$, and the production function is Cobb-Douglas, $f(y, h, k) = yh^a k^{(1-a)}$ with parameter $a = \frac{2}{3}$. The bankruptcy re-access parameter $\lambda = .036$ generates the statutory 7 year exclusion period.

The remaining 8 parameters including the discount factor β, the unemployment benefit z, the utility penalty of bankruptcy χ, the entry cost of firms κ, the fixed cost of operations f_c, the flow from leisure η, the human capital appreciation $p_{+\Delta}$ rate, and the human capital depreciation $p_{-\Delta}$ rate are calibrated jointly to match 8 moments: the fraction of households with liquid asset to income ratios less than 1%, the immediate consumption loss from unemployment, the bankruptcy rate, the unemployment rate, the relative volatility of unemployment to productivity, the autocorrelation of unemployment, the wage growth of 25 year olds, and the long term consumption losses from layoff. We do not directly target the duration elasticity or replacement rate elasticity.

The household discount factor $\beta = .987$, which implies a discount rate of about 5% per annum, is calibrated to match the fact that 25.4% of households have a ratio of liquid assets to annual gross income less than one percent.[28]

The unemployment benefit is set to a constant, $z(k) = .102\ \forall k$, in order to match the observed consumption losses following job loss.[29] This value of z yields an average replacement rate of approximately 40% for the lowest human capital workers (Shimer [2005]), but implies replacement rates significantly lower replacement rate of 10% for higher human capital workers, in line with Chodorow-Reich and Karabarbounis [2013].

The labor vacancy posting cost $\kappa = .034$ is chosen to target a mean U6 unemployment

[28] See Herkenhoff [2013]. The data is from the SCF (and it predecessor survey the Survey of Consumer Credit). For each household, we sum cash, checking, money market funds, CDS, corporate bonds, government saving bonds, stocks, and mutual funds less credit card debt over annual gross income. We take the mean of this liquid asset to income ratio across households in each survey year, and then we average over 1970 to 2007 to arrive at the moment.

[29] Browning and Crossley [2001] find 16% consumption losses after 6 months of unemployment for Canadians, and as they explain, scaling food consumption losses in Gruber [1994] results in 15% consumption losses in the year of layoff for US households in the PSID. We therefore target a 15% consumption loss from the quarter prior to initial displacement until the end of the 1st year of layoff, 4 quarters after initial displacement.

rate of 8.9% which is the 1994-2007 average.[30]

We set the bankruptcy utility penalty $\chi = .078$ to generate the average bankruptcy rate in the US from 1970-2007 of approximately .1% per quarter.[31]

The processes for human capital are calibrated to generate .81% wage growth per quarter while employed (if we assume when agents are 'born' they are 23, then we compute this moment as the growth rate of wages among 25 year olds in the model), as well as the long term consumption losses of displaced households.[32] These processes are governed by two parameters $p_{-\Delta}$ and $p_{+\Delta}$.

$$H(h,U) = h' = \begin{cases} h - \Delta & \text{w/ pr. } p_{-\Delta} \text{ if unemployed} \\ h & \text{w/ pr. } 1 - p_{-\Delta} \text{ if unemployed} \end{cases}$$

$$H(h,W) = h' = \begin{cases} h + \Delta & \text{w/ pr. } p_{+\Delta} \text{ if employed} \\ h & \text{w/ pr. } 1 - p_{+\Delta} \text{ if employed} \end{cases}$$

In the calibration below, the grid for human capital, $h \in [.5, .6, .7, .8, .9, 1]$, as well as the step size, $\Delta = .1$, between grid points are taken as given. Our estimates are $p_{-\Delta} = .143$ and $p_{+\Delta} = .078$, which produce similar human capital processes at Ljungqvist and Sargent [1998]. Once every year-and-a-half, unemployed agents in the model expect to fall one rung on the human capital ladder. This implies between 10% to 20% earnings losses (depending on the initial human capital), which is smaller than the 30% per year Ljungqvist and Sargent [1998] target.

In terms of the flow utility of leisure, we follow most of the quantitative search and matching literature by setting η to target a labor market moment. We choose $\eta = .237$ to match the autocorrelation of unemployment since the flow utility of leisure determines unemployed households' willingness to remain out of work.

We calibrate the fixed cost of operations for firms $f_c = .097$, which determines how sensitive firms are to productivity shocks, to match the observed volatility of unemployment to productivity.

Table 8 summarizes the parameters, and Table 9 summarizes the model's fit relative to the targeted moments. The model will success at replicating the new empirical facts on debt

[30]Since there is no concept of "marginally-attached" workers or part-time employment in the model, U6 is a better measure of unemployment for the model. The data is available from 1994:Q1 to present.

[31]The bankruptcy rate is .41% per annum from 1970-2007 according to the American Bankruptcy Institute (accessed via the Decennial Statistics).

[32]Our measure of wage growth is the median 2-year real-income growth for households aged between 25 and 30 in the PSID between 2005 and 2007. The median growth rate among this subset of households was 6.75% over that time period. Converting that to quarters yields a .81% quarterly income growth rate. We use Saporta-Eksten [2013]'s estimates of long-run consumption losses, and target an 8% consumption loss 8 quarters after initial displacement.

and duration of unemployment, but the model is unable to match several moments.

First, with constant UI, business cycle moments cannot be matched using a Hagedorn and Manovskii [2008] calibration since there is heterogeneity on both sides of the market (we introuce the fixed cost of operation to squeeze the surplus of firms, but raising the fixed cost can, at most, make only the lowest type firms sensitive to business cycles; likewise raising the value of leisure or payments to the unemployed suffers from a similar problem, namely, the lowest type may be indifferent between working and not working, but all other types will not).[33] When trying to generate borrowing, this failure to match business cycle moments plays an important role: Lowering the discount factor would be the best way to generate borrowing but doing so only exacerbates the models ability to match business cycle facts. The more impatient are agents, the more they want to work immediately, regardless of productivity. As a result, generating the fraction of agents borrowing in the economy and simultaneously producing business cycle facts are at odds with one another. The growth rate of human capital early in life directly controls the growth rate of wages, but it also impacts the fraction of households who borrow against future earnings; this introduces an additional tension, which is that rather than simply setting the discount factor to generate borrowing, the minimization routine attempts to generate borrowing by choosing steep wage profiles since reductions in the discount factor distort several other moments. We discuss this more in Appendix D.

7.1 Non-Targeted Moments: Model Estimates of Duration and Replacement Rate Elasticities

To calculate the sensitivity of agents in the model to credit, we first define the credit limit as the maximum of either the level of debt where the bond price first becomes zero or the exogenous debt limit $\underline{b}$. We isolate newly laid off agents with debt (let I_δ denote this set of agents), we move the agents $\Delta b > 0$ closer to their borrowing limit, and then we compute the implied unemployment duration reduction, weighted by the observed distribution of job losers,[34]

$$\Delta Dur_t = \int_{I_\delta} Dur_t(b - \Delta b, h, k; \Omega) d\mu - \int_{I_\delta} Dur_t(b, h, k; \Omega) d\mu$$

Independent of the definition of the debt limit, unused credit declines by Δb and the duration increases by ΔDur_t. Let the subscript $_{-1}$ denote yesterday's value (e.g. k_{-1}

[33] Innovative work by Lise and Robin [2013] makes the sum of UI and leisure (their model has linear utility) large, and a function of a polynomial in the worker type and aggregate state (as well as the interaction of the two polynomials). This type of fix would eliminate the economics of the problem at hand by culling any incentive of agents in the model to borrow and it would cause the model to miss the consumption drop upon layoff.

[34] The expected duration is based on the 1-quarter ahead implied job finding rate, based on the search policy function. In quarters, for large M, the expected duration is given by, $Dur_t(b - \Delta b, h, k; \Omega) = \sum_{m=1}^{M} mp(\theta_t(h, k_t^*(b - \Delta b, h, k; \Omega); \Omega)) * (1 - p(\theta_t(h, k_t^*(b - \Delta b, h, k; \Omega); \Omega)))^{(m-1)}$.

Table 8: Summary of Model Parameters.

Variable	Value	Description
		Pre-Calibrated
ρ	0.8934	Autocorrelation of Productivity Process
σ_e	0.00548	Std. Dev. Of Productivity Process
r_f	4%	Annualize Risk Free Rate
δ	10%	Quarterly Layoff Rate
ζ	1.6	Matching Function Elasticity
σ	2	Risk Aversion
α	.66	Household share of income
a	.66	Cobb-Douglas Labor Share
λ	0.036	Bankruptcy Re-Access
$\underline{b}$	-.5	Non-binding debt limit

Variable	Value	Description
		Jointly-Estimated
κ	0.034	Firm Entry Cost
β	0.988	Discount Factor
z	0.103	UI
$p_{-\Delta}$	0.143	Depreciation Rate of Human Cap.
$p_{+\Delta}$	0.078	Appreciation Rate of Human Cap.
f_c	0.098	Fixed Cost
η	0.237	Flow Utility of Leisure
χ	0.078	Bankruptcy Utility Penalty

Table 9: Model Calibration

	Model	**Target**	**Variable**	**Value**	**Source**
Unemployment Rate	8.60%	8.90%	κ	0.034	BLS, U6 1994-2007
LQTI<1%	0.09	0.254	β	0.988	SCF, 1974-2007
Consumption Drop 1 Yr After Layoff	0.85	0.84	z	0.103	Browning & Crossley (2001)
Consumption Drop 2 Yrs After Layoff	0.97	0.92	$p_{-\Delta}$	0.143	Saporta-Eksten (2013)
Quarterly Income Growth Rate 25yo	1.08%	0.81%	$p_{+\Delta}$	0.078	PSID, 2005-2007
Vol U/ Vol y	2.17	9.5	f_c	0.098	Shimer (2005)
Autocorr Unempl	0.72	0.94	η	0.237	Shimer (2005)
Bankruptcy rate	0.008%	0.100%	χ	0.078	ABI, 1970-2007

is capital yesterday). We annualize the agent's earnings prior to layoff $Y_{t-1} = \int_{I_\delta} 4 * f(y_{-1}, h_{-1}, k_{-1}; \Omega_{-1}) d\mu_{-1}$, and then we calculate the model implied duration elasticity,

$$\epsilon_{dur,t} = \frac{\Delta Dur_t}{\left(\frac{\Delta b}{Y_{t-1}}\right)} = -.718$$

In other words, if unused credit to income increased by 10% (the reverse of the model experiment, hence the sign change), then agents would take .8 weeks longer to find a job. This falls within the range found empirically using both the Saiz [2010] instrument and Gross and Souleles [2002]. There are potentially important differences between the local average treatment effect identified by the IV, and the elasticity calculated here. We are exploring better ways of comparing the two numbers.

The wage gains of displaced workers with greater amounts of credit are also a non-targeted moment. However, as we explain below, we find that the model produces a near-zero earnings replacement rate elasticity, whereas in the data, the elasticity is relatively large. If wage gains reflect productivity gains, then the model simulation exercise below is a lower bound on the impact of credit on productivity and output.[35]

We measure the earnings replacement rate elasticity as follows. Defining the credit limit as before (where the bond price first hits zero), we isolate newly laid off agents with debt (this set of agents is defined by I_δ as before), and we move the agents $\Delta b > 0$ closer to their borrowing limit. We then compute the counterfactual expected annualized earnings (which implicitly includes zero earnings outcomes) when we move the agents $\Delta b > 0$ closer to their borrowing limit, $Y_t(b - \Delta b) = \int_{I_\delta} p(\theta_t(h, k_t^*(b - \Delta b, h, k; \Omega); \Omega)) * 4 * f(y, h, k_t^*(b - \Delta b, h, k; \Omega)) d\mu$. Likewise, for the case in which the agents remain with the same debt, $Y_t(b) = \int_{I_\delta} p(\theta_t(h, k_t^*(b, h, k; \Omega); \Omega)) * 4 * f(y, h, k_t^*(b, h, k; \Omega)) d\mu$. We define the difference in replacement earnings as $R_t = \frac{Y_t(b-\Delta b)}{Y_{t-1}} - \frac{Y_t(b)}{Y_{t-1}}$. In this experiment, unused credit declines by Δb and replacement earnings change by R_t, so the model implied wage elasticity is given by,

$$\epsilon_{Rep,t} = \frac{R_t}{\left(\frac{\Delta b}{Y_{t-1}}\right)} = .0062$$

The model produces a small positive earnings replacement rate elasticity of +.0062, whereas in the data, the earnings replacement rate elasticity is approximately -.15 (the sign flips since we are reducing the unused credit available to households). To understand why this is the case, we can decompose earnings losses into 2 offsetting components: (i) the additional debt increases job finding rates, which tends to raise replacement earnings, and (ii) the additional

[35] With random search and Nash-Bargaining, wage gains may simply reflect differences in outside options. Then the model's results may in fact be over-estimates of productivity gains from credit access. But the fact that workers with more credit take longer to find jobs and systematically work for larger, older firms (who in general pay greater wages and are more capital intensive) indicate that workers are changing search behavior, not just bargaining for higher wages.

debt reduces the capital intensity of submarkets searched by agents, which tends to lower replacement earnings. We can compute each of these components separately. Define the change in job finding rates as, $JF_t(b - \Delta b) = \int_{I_\delta} p(\theta_t(h, k_t^*(b - \Delta b, h, k; \Omega); \Omega))d\mu$. Likewise, for the case in which the agents remain with the same debt, $JF_t(b) = \int_{I_\delta} p(\theta_t(h, k_t^*(b, h, k; \Omega); \Omega))d\mu$. The model implied job finding elasticity is given by,

$$\epsilon_{JF,t} = \frac{JF_t(b - \Delta b) - JF_t(b)}{\left(\frac{\Delta b}{Y_{t-1}}\right)} = .170$$

With more debt, workers find jobs more quickly. This tends to increase the replacement earnings of agents. Define the capital intensity rate of submarkets in which agents search as, $K_t(b - \Delta b) = \int_{I_\delta} 4 * f(y, h, k_t^*(b - \Delta b, h, k; \Omega))d\mu$.[36] Likewise, for the case in which the agents remain with the same debt, $K_t(b) = \int_{I_\delta} 4 * f(y, h, k_t^*(b, h, k; \Omega))d\mu$. The model implied capital intensity elasticity is given by,

$$\epsilon_{K,t} = \frac{K_t(b - \Delta b) - K_t(b)}{\left(\frac{\Delta b}{Y_{t-1}}\right)} = -0.3092$$

With more debt, workers search in submarkets with lower capital intensity. This tends to decrease the replacement earnings of agents. The combination of the two effects yields the near-zero replacement earnings elasticity.

8 Main Quantitative Experiment

Our main experiment is designed to understand how fluctuations in consumer credit limits impact the macroeconomy. In particular, we study the way changes in borrowing limits impact the path of output, productivity, and employment during the 2007-2009 recession. We do so by comparing aggregate outcomes across two economies, both of which have the same beliefs about debt limit transitions $P_{\underline{b}}$:

1. **Tight Debt Limit Economy:** The debt limit tightens from $\underline{b} = -.5$ (a non-binding value) to $\underline{b} = -.1$ in 2008-Q4 (the first quarter in which the aggregate consumer credit limit declined), and stays there permanently.

2. **Constant Debt Limit Economy:** The debt limit $\underline{b} = -.5$ remains constant throughout the simulation.

In the experiments below, both economies are simulated in their ergodic stochastic steady states with the non-binding debt limit, $\underline{b} = -.5$, for a large number of periods. We then

[36] Note the slight misnomer, as we use output here since capital is proportional to output.

feed in a realized set of shocks that replicates, exactly, the path of the Fernald et al. [2012] productivity residuals from 1974-Q1 to 2012-Q4. The borrowing limit is held constant at $\underline{b} = -.5$ through 2008-Q4 in both economies, for simplicity. In 2008-Q4, one economy has the limit tighten to $\underline{b} = -.1$, and it remains there permanently.

We impose that both economies have the same beliefs over debt transitions, which are, on average, rational. Let $p_{l,l}$ be the probability of remaining in the 'low' debt limit state, $\underline{b} = -.1$, and let $p_{h,h}$ be the probability of remaining in the 'high' debt limit state, $\underline{b} = -.5$. Then the transition matrix for the debt limit $\underline{b}$ is given by,

$$P_{\underline{b}} = \begin{pmatrix} p_{l,l} & 1 - p_{l,l} \\ 1 - p_{h,h} & p_{h,h} \end{pmatrix}$$

Agents understand that if the debt limits tighten, it is permanent, so we set $p_{l,l} = 1$. And, agents also understand that once every 34 years (from 1974 to 2008), debt limits will tighten, so we set $p_{h,h} = .9926$.

8.1 Model Results

Figure 3 illustrates the path for the exogenous component of productivity y and the path for the borrowing limit $\underline{b}$. These are the two inputs in the experiment. Each plot contains two dashed lines that correspond to differing degrees of debt limit tightening. The dashed blue line corresponds to the economy where limits tighten to $\underline{b} = -.1$, and the dash-dot red line corresponds to the economy where limits tighten to $\underline{b} = -.2$.

Firstly, Table 10 illustrates what the tightening of debt limits does to borrowing in the model economies. The model economies see reductions in the fraction of households borrowing of 3.10 percentage points, and 1.01 percentage points, respectively. Economy-wide debt to income ratios fall by 1.06 percentage point and .46 percentage points respectively. In the data, the fraction of households that stopped borrowing fell by 6.77 percentage points from 2007 to 2010 (measured in the SCF) while the debt to income ratio fell by .86 percentage points from 2007 to 2010 (measured in the SCF).[37]

Figure 4 plots the percentage change in employment during the 2007-2009 recession across the economy with a tighter debt limit versus the economy with a fixed debt limit. When debt limits tighten, employment tends to increase, persistently. The mechanism is that with looser credit limits, unemployed households borrow to smooth consumption while thoroughly searching for capital-intensive jobs. If debt limits tighten, they lose their ability to self-insure, and, as a result, take low-capital-intensity jobs that are relatively quick to find. In other words, when limits tighten, low-asset job losers take relatively less productive

[37] While not reported here for the sake of space, the bankruptcy rate reaches .8% in the quarter in which limits are tightened, which is in line with ABI bankruptcies per capita.

Table 10: Reduction in Borrowing When Borrowing Limit Tightens, Model v. Data.

	Δ Fraction of HHs Borrowing	Δ DTI
Debt limit tightened from $\underline{b} = -.5$ to $\underline{b} = -.1$	-3.10%	-1.06%
Debt limit tightened from $\underline{b} = -.5$ to $\underline{b} = -.2$	-1.01%	-.46%
Data	-6.77%	-.86%

Notes: All Differences Computed using 2007 and 2010 SCF. DTI is Change Unsecured Revolving Consumer Credit to Annual Family Income. Fraction Borrowing Change is Difference in Fraction of Households Carry Positive Balances. Means Weighted Using Survey Weights. Model statistics calculated as difference in average of quarterly values over same corresponding years.

employment opportunities.[38] This introduces a strong tension between recovery speed and recovery health, as workers find jobs more quickly but these jobs are of lower quality.

Because of this mechanism, Figure 5 shows that measured labor productivity, defined as output over employment, declines when debt limits are tightened. The economy in which debt limits tighten the most has .25 percentage points lower labor productivity as compared to the economy with constant debt limits, and this productivity gap persists throughout the recovery.

While the impact of tighter debt limits on capital per worker is unambiguous, the impact of tighter debt limits on aggregate output is theoretically ambiguous: households find jobs faster, but the jobs workers find are less productive. Figure 6 shows that quantitatively the reduction in capital per worker is so severe that output falls by .1 percentage points.

As Figure 7 shows, the aggregate capital stock held by entrepreneurs drops severely relative to the economy in which debt limits are held constant. This is entirely driven by new entrepreneurial entrants posting more vacancies in submarkets with less capital. The time it takes for the aggregate capital stock to recover to its pre-recession levels is as much as 6 quarters longer in the economy in which debt limits tighten.

Figure 8 plots the percentage change in the correlation between human capital, h, and firm capital, k, during the 2007-2009 recession. Figure 9 plots the corresponding percentage change in the Spearman rank correlation coefficient between human capital, h, and firm

[38] This mechanism is similar to earlier studies of unemployment insurance, pre-cautionary savings, and productivity, such as Acemoglu and Shimer [1998] and Acemoglu and Shimer [2000]. What makes the mechanisms different is that credit lines can be drawn down before an unemployment spell begins, producing strong offsetting effects on job finding behavior in the long-run (Herkenhoff [2013]). Credit lines are also supposed to be repaid which means bankruptcy provide workers with an alternate form of self-insurance that may be more valuable in downturns when credit is scarce (which occurs in the present experiment). What makes the credit mechanism quantitatively important is that more unemployed households carry credit cards than claim unemployment benefits.

capital, k, as well (as explained in the introduction, workers are ranked by h, and firms are ranked by k, and the Spearman Rank correlation coefficient is the resulting correlation between the numeric ranks of workers and firms). The raw correlation coefficient between worker human capital and firm physical capital is approximately $+.33$.

As Figures 8 and 9 show, on average, the correlation between human capital and firm capital rises during recessions.[39] The reason is that constrained, low-human-capital workers, become relatively more constrained during recessions and sort into less capital-intensive firms. Unconstrained, higher human capital workers, have a buffer stock of savings and are able to keep sorting into firms with relatively high levels of capital, even during recessions. The empirical literature on the cyclicality of sorting is very thin. Bagger et al. [2013] emphasizes long-run sorting trends, but their time series reveals that sorting accelerated during the Danish recession in the early 1990s, and then declined in the tranquil 2000s. This is consistent with the model's predictions.[40]

Figures 8 and 9 also show that in the economy in which debt limits are tighter, these standard measures of sorting *improve*. The mechanism behind this sorting inversion is that unemployed agents with low-human-capital cannot borrow to smooth consumption while thoroughly searching for jobs. Therefore, they take jobs that are less-capital-intensive, but more abundant. On average, since low human capital workers are less productive (recall the assumption of supermodularity), tighter debt limits force these 'low quality' workers to take 'low quality' jobs. As such, standard measures of sorting improve, even as output falls, since they do not take into account the investment decisions of firms. In this economy, these standard measures of sorting are not good proxies for either productivity or output.

8.2 Robustness: Capital Investment, Liquidation, and Interest Rate Shocks

We conduct three robustness exercises in Appendix E. First, we allow for the entrepreneurs to invest in capital over time, mitigating concerns about both quits and on-the-job-search. With costless adjustments to entrepreneur capital, there would never be a reason to quit or change jobs. We find that our duration elasticity and wage elasticity are largely unchanged. Second, we allow for liquidation value of firm capital, but the model results change very little.

Lastly, we conduct a monetary policy experiment, reducing risk-free interest rates, r_f, from 4% to 0% during the simulated 2007-2009 recession. We see a similar sorting inversion as unemployed low-human-capital borrowers are better off when interest rates fall, taking higher capital jobs, but high-human capital savers are worse off, taking lower capital jobs.

[39] In a model with linear utility, Lise and Robin [2013] find similar countercyclical sorting patterns among certain subgroups of households.

[40] Moscarini and Vella [2008] use the CPS to study occupational sorting, and they find that there is less occupational sorting in recessions.

However, when interest rates fall, entrepreneurs' credit constraints are loosened, and they can post more vacancies with greater capital per vacancy.

The impact of reducing interest rates on output is theoretically ambiguous: some households have greater self-insurance and take better jobs, whereas other households lose wealth and take worse jobs. Quantitatively, output falls by less when interest rates drop during a recession. The reason is that in the economy with lower interest rates, entrepreneurs post more vacancies with greater capital. As a result, the number of vacancies per worker, averaged across submarkets, $\sum_{h,k,t} \frac{v_t(h,k;\Omega)}{u_t(h,k;\Omega)}$, falls during the recession, but falls by less in the economy in which the risk free rate also drops. This is because the effective cost of posting a vacancy, $\kappa + (1 + r_f)k$, moves 1 for 1 with the interest rate.

As a result, the aggregate capital stock held by firms drops by less in the economy in which the risk free rate falls. Since capital and vacancies do not fall by as much, the reduction in output is .25% less severe in the lower interest rate economy. In the economy in which interest rates drop, we also find that productivity increases by approximately .1% more than the economy with a constant interest rate. The reason is that even though employment increases, the output gains from the added capital are enough to generate labor productivity increases following an interest rate decline.

Figure 3: Experiment Input: Exogenous Aggregate Productivity (y) and Borrowing Limit $\underline{b}$, 2007-2009 Recession

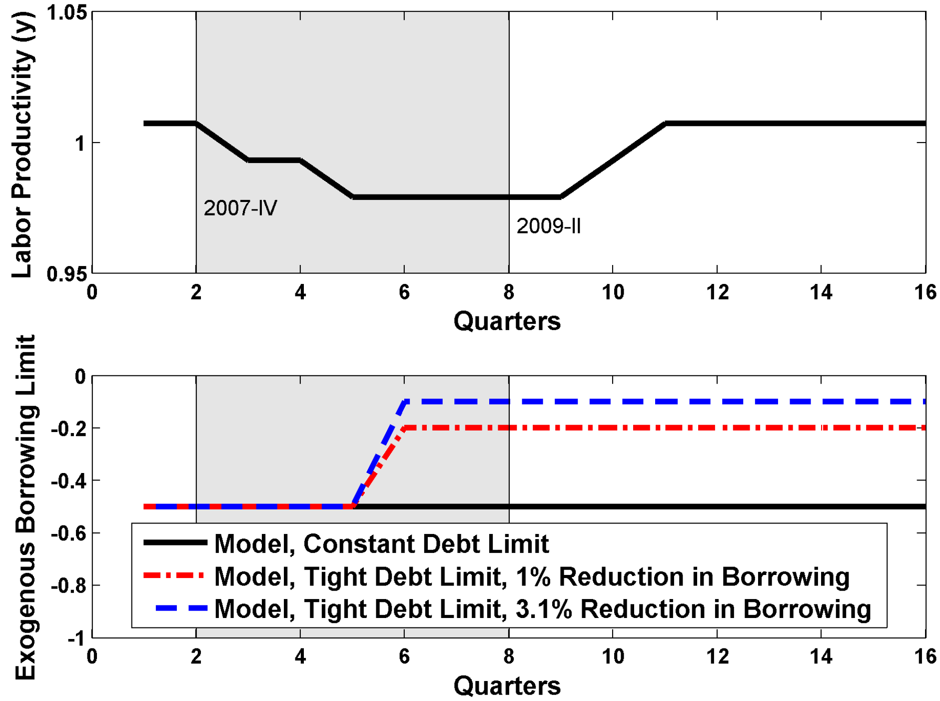


Figure 4: Percentage Change in Employment Per Capita

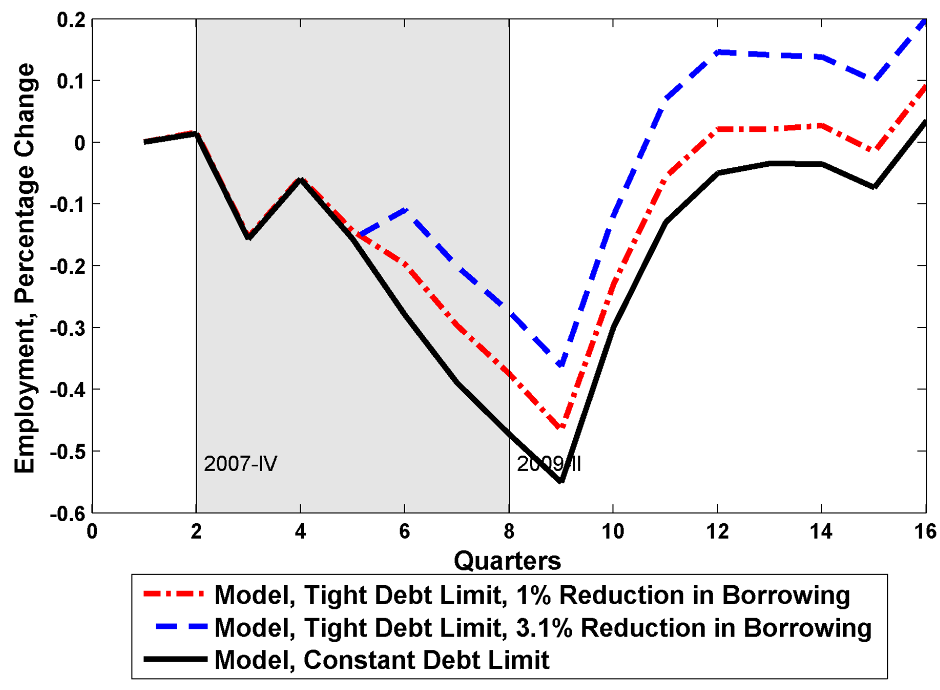


Figure 5: Labor Productivity, 2007-2009 Recession

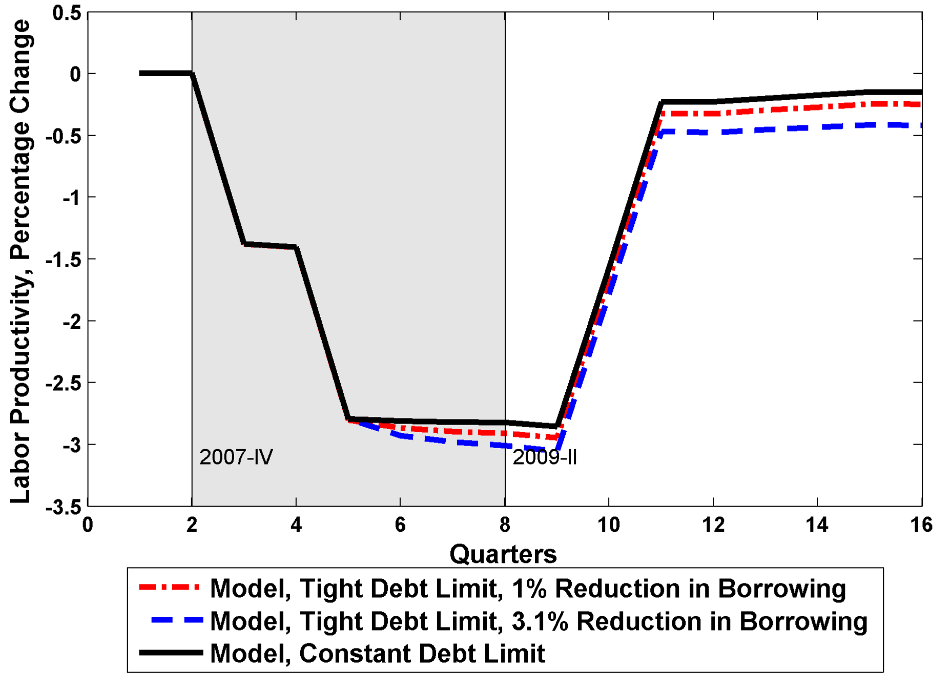


Figure 6: Aggregate Output

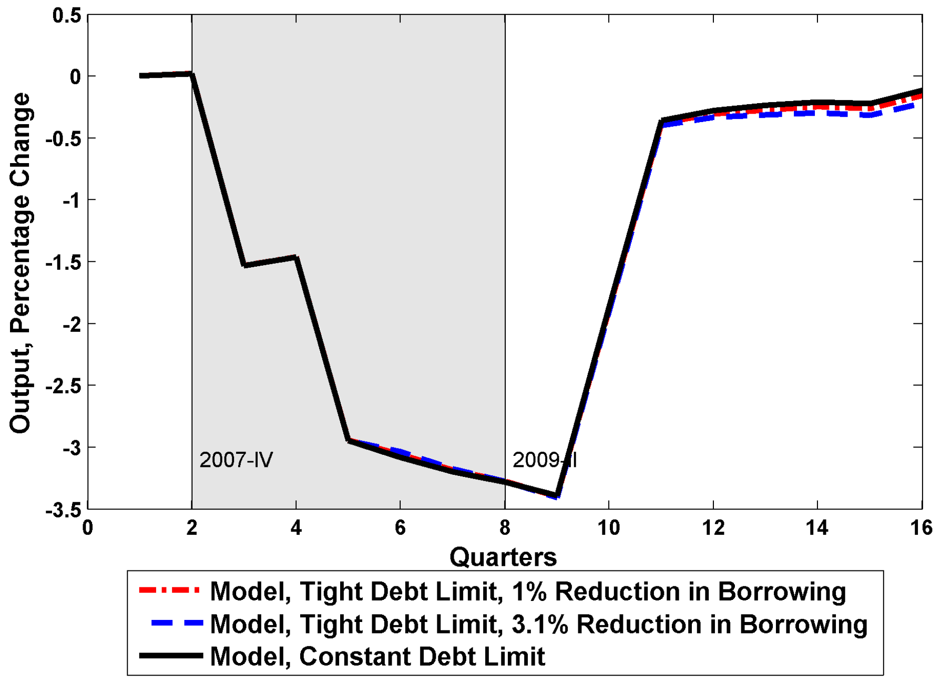


Figure 7: Aggregate Firm Capital, 2007-2009 Recession

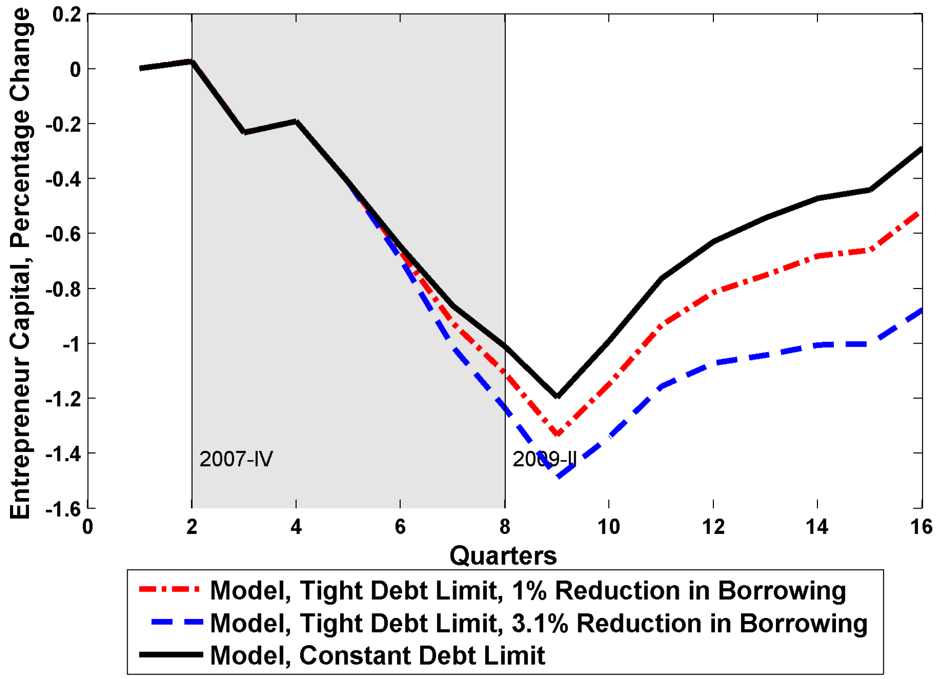


Figure 8: Correlation Between Human Capital (h) and Firm Capital (k)

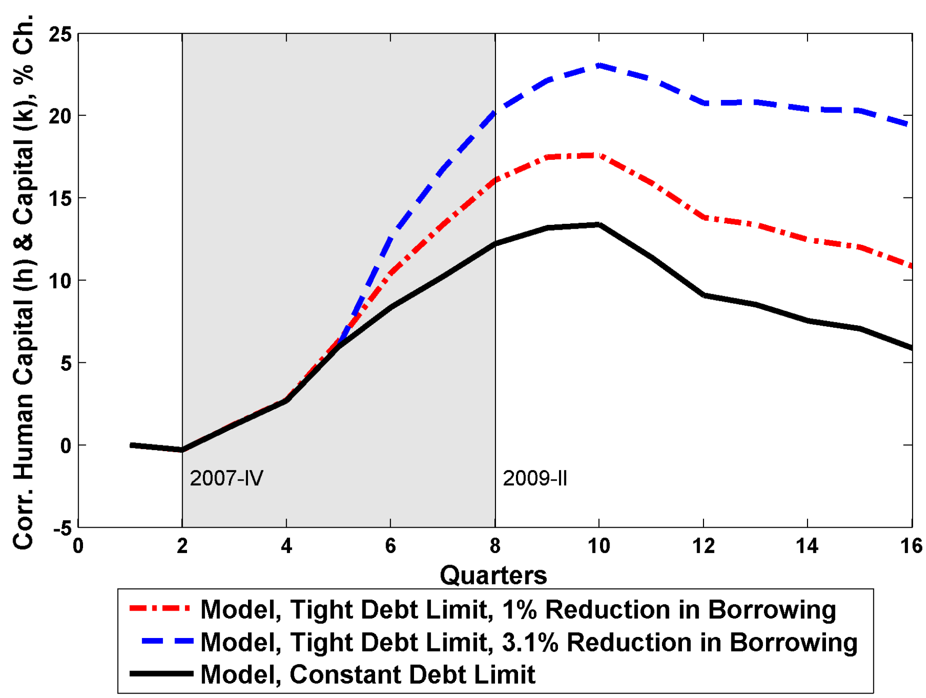
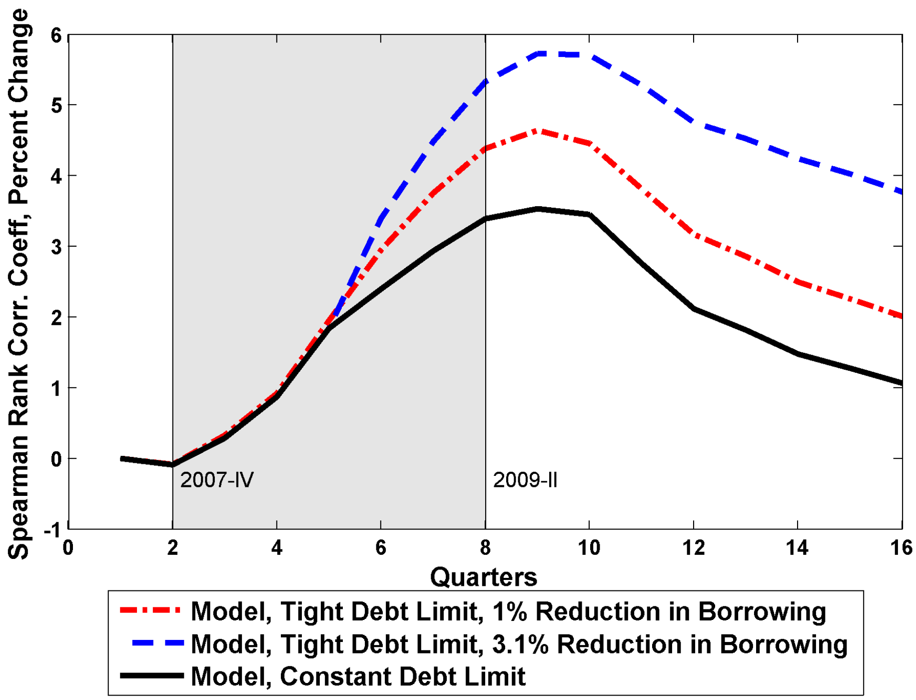


Figure 9: Spearman Rank Correlation Coefficient Between Human Capital (h) and Firm Capital (k)



9 Conclusions

This paper makes two contributions. First, we estimate the impact of credit constraints on job finding rates and subsequent replacement wages of displaced workers using new administrative data. We find that medium-tenure displaced mortgagors, in response to being able to replace 10% of their annual income with revolving credit, take .3 to 1 week longer to find a job but obtain an earnings replacement rate that is .5% to 1.5% greater.

Second, we estimate a directed search model in which households are credit constrained and must sort among heterogeneous firms in order to understand how fluctuations in debt limits impact productivity, output, and employment. We find that tighter debt limits during recessions may increase employment during the recovery, but depress both productivity and output. This tension between the speed of recovery and health of recovery is at the heart of the mechanism: tighter debt limits force constrained households to cut their job search short, taking relatively unproductive jobs that are more abundant.

These results have important implications for public policy. Understanding the elasticity of the job finding rate with respect to credit is necessary to explore optimal unemployment insurance policy and, in particular, the potential substitutability of unemployment benefits with credit. In follow-up work we plan to explore this area of research in great detail. Overall, we see this paper as an initial step toward our broader research agenda of understanding how consumer credit and other private consumption smoothing mechanisms impact labor markets.

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A Data Sources

Employer reports are based on the ES-202 which is collected as part of the Covered Employment and Wages (CEW) program (run by BLS). One report per establishment per quarter is filed. On this form, wages subject to statutory payroll taxes are reported.

The employment records are associated with a firm's State Employment Identification Number (SEIN). This is an identifier based on an employer within a given state, and it is, in general, not an identifier of the establishment of the worker. Minnesota is the only state to collect establishment identifiers, and in all other states, an imputation based on place-of-work is used to generate establishment level identifiers. In general, workers are included in the dataset if they earn at least 1$ from any employer.

The Quarterly Census of Employment and Wages (QCEW) contains firm level data which is collected in each state. This dataset includes information on industry, ownership, and worksite. Firm age and size are then taken from the Business Dynamics Statistics (BDS) which is a private-sector longitudinal business database.

The demographic data in the LEHD comes from the 2000 census as well as social security records, and tax returns. These are linked by social security number with the unemployment insurance data. In the LEHD, social security numbers are not present, rather there is a scrambled version called a Protected Identification Key (PIK).

The main of the demographic information is the Person Characteristic File (PCF), and the Composite Person Record (CPR). Information on sex, date of birth, place of birth, citizenship, and race. CPR contains annual place of residence information.

B Additional Robustness Checks

B.1 Alternate Identification Strategy Based on Gross and Souleles (2002)

Gross and Souleles [2002] exploit exogenous variation in the timing of credit limit increases solely due to the length of time since an account was opened. Conditional on age and income, which are two observables in our dataset, we exploit plausibly exogenous heterogeneity in account ages as an instrument for credit limits.

Following Gross and Souleles [2002], we hypothesize and argue below that the age of the oldest account is a valid instrument for credit limits. For that to be true, the age of the oldest account must be a strong determinant of credit limits (relevance), but not have an impact on employment prospects except through credit limits (exogeneity). The first stage of the 2-step instrumental variable regression demonstrates the relevance of the age of the oldest open account for credit limits.

Conditional on the age and income of a person, there are a number of reasons that are orthogonal to labor market outcomes that would result in different ages of credit accounts. Natural churn of accounts expiring and accounts opening will generate different values for the age of the oldest open credit account. Age of the oldest open account may also be correlated with assets, education, earnings, and other demographic variables, and so we include proxies for equity and auto holdings, imputed education, lagged earnings, and standard demographic controls such as tenure, sex, race, etc. to address this, as well as home equity proxies.

Table 11 illustrates the main results when we instrument the unused revolving credit to income ratio using the age of the oldest tradeline. Columns (1) through (4) illustrate the impact of unused credit on unemployment durations. Column (1) is the baseline specification, Column (2) adds in an equity proxy which is the highest mortgage balance on file less the current balance. Column (3) adds in controls for home equity lines of credit (HELOCs), summing the limit across all available HELOCs. Column (4) includes all controls, and the coefficient estimate of .264 implies that being able to replace 10% more of prior annual earnings with unused credit increases the duration of non-employment by .026 quarters, or roughly $\frac{1}{3}$ of a week. Columns (5) through (8) estimate the impact of unused credit on the earnings replacement rate, 1 year after layoff. Column (8), which includes all available controls, implies that a 10% increase in the unused credit limit ratio increases the replacement rate of earnings 1 year after layoff by .63%.

B.2 Alternate Measures of Personal Financial Constraints: Total Credit, Revolving Credit Including HELOCs, and Credit Scores

In Table 12, we use alternate endogenous regressors: (i) total unused credit, including all types of secured (including HELOCs and mortgage debt) and unsecured debt, and (ii) credit scores (this corresponds to TransUnions bankruptcy model, and ranges from 0 to 1000). We define 'total unused credit to income' as the total credit limit less the amount currently borrowed over annual earnings, where the ratio is measured 1 year prior to layoff.[41] Columns (3)-(6) of Table 12 illustrates the results. In general, total unused credit to income is less

[41] The Total Credit Limit is formally the TransUnion variable "Total High Credit/Credit Limit" which is sum of actual credit limits across all types of debt, or if the credit limit is not stated, it is the highest observed prior balance. This measure of credit includes secured credit lines like home equity lines of credit and installment credit, as well as auto loans, and other personal finance loans.

Table 11: Instrument is age of oldest tradeline (any credit account), based on Gross and Souleles [2002]. Dependent variable in Columns (1) through (5) is duration (in quarters). Dependent variable in Columns (5) through (8) is replacement earnings. Each column progressively adds more home equity controls.

Dep. Var.	(1) Duration	(2) Duration	(3) Duration	(4) Duration
Revolving Unused Credit to Income	0.274***	0.254***	0.255***	0.262***
	(0.0914)	(0.0931)	(0.0919)	(0.0924)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0658	0.0658	0.0703	0.0705
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

Dep. Var.	(1) Replacement Rate	(2) Replacement Rate	(3) Replacement Rate	(4) Replacement Rate
Revolving Unused Credit to Income	0.0616***	0.0782***	0.0777***	0.0637***
	(0.0152)	(0.0160)	(0.0157)	(0.0157)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	**Y**	N	N	**Y**
Equity Proxy	N	**Y**	N	**Y**
HELOC Limits	N	N	**Y**	**Y**
R2 First Stage	0.0658	0.0658	0.0703	0.0705
Angirst Pischke FStat Pval	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0
Round N	19000	19000	19000	19000

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include both lagged real annual earnings, and cumulative lagged real annual earnings to proxy for assets. Equity proxy is highest observed mortgage balance less current balance. HELOC limits is sum of all home equity line of credit limits.*

potent than revolving credit. Installment loans and other auto loans are difficult to adjust upon job loss, even if the household has had large balances in the past (indicating a large borrowing capacity). Credit scores produce a similar sign and significance level as unused credit, but the magnitudes of the coefficients are difficult to interpret.

B.3 Correlation of Unemployment Durations and Credit Limits in SCF, Controlling for Assets

In the SCF, we can compute the raw correlation between unused credit limits and unemployment durations, controlling for a host of assets, including home values. Table 13 demonstrates a strong correlation between unused credit card limits and unemployment durations, subject to attenuation bias. The 'Unused Unsecured Limit to Income' refers to unused credit card limits (as of the survey date) over annual gross family income (over the prior year). Unemployment duration measures weeks spent unemployed over the past 12 months prior to the survey. It is measured in weeks, and does not distinguish individual unemployment spells.

Column 1 of Table 13 shows that simple regressions of unemployment duration on unused credit card limits reveal a strong positive correlation, even after controlling for income and liquid assets. Columns 2 and 3 impose age restrictions and add basic demographic controls, but the positive and significant relationship persists. Column 4 adds in all available categories of illiquid assets, and finally Column 5 restricts the dataset to mortgagors (as is the case in the LEHD/TransUnion sample considered in the text). The strong positive and significant relationship between unused credit limits and unemployment durations persists. An unused credit limit worth 10% of prior annual family income is associated with 1 week longer unemployment spells, very similar to estimate in the LEHD/TransUnion sample considered in the text.

B.4 House Prices and the Relationship Between Credit, Non-Employment Durations, and Replacement Rates

Table 14 illustrates the main regressions estimated with OLS, with and without housing price controls. The house price control we include in the regression is the OFHEO All-Transaction House Price Index for MSAs.[42] We control for house prices at the time of the layoff, and we find that the correlation between the unused credit limit ratio and non-employment durations changes very little. Likewise, the replacement rate 1 year after layoff is hardly impacted by the inclusion of house prices as controls.

Because house prices increase does not imply households are wealthier. A households may attempt to sell the house, but they must buy a new one or rent thereafter. We find

[42] This is publicly avaiable from the OFHEO website. The index is normalized to 100 in 1995.

Table 12: Alternate Endogenous Regressors. Columns (1) through (6) use the supply elasticity as an instrument. Columns (1) and (2) use revolving credit inclusive of HELOCs as the endogenous regressor, Columns (3) and (4) use total unused credit (secured and unsecured, revolving and non-revolving) as the endogenous regressor, and Columns (5) and (6) use credit scores as the endogenous regressor. Columns (7) through (12) are similar, except the instrument is the WRI. (Source: 2002-2007 LEHD/TransUnion)

	Saiz House Supply Elasticity					
	(1)	(2)	(3)	(4)	(5)	(6)
	Duration	Replacement Rate	Duration	Replacement Rate	Duration	Replacement Rate
Revolving Unused Credit to Income	0.734**	0.0789				
	(0.286)	(0.0549)				
Total Unused Credit to Income			0.617**	0.0678		
			(0.251)	(0.0449)		
Credit Score					0.00170***	0.000168**
					(0.000403)	(7.72e-05)
Demographic Controls	Y	Y	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y	Y	Y
Lagged Earnings Controls	Y	Y	Y	Y	Y	Y
R2 First Stage	0.0849	0.0849	0.0703	0.0703	0.125	0.125
Angrist Pischke FStat Pval	0	0	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0	0	0
Round N	19000	19000	19000	19000	19000	19000
Pval J test Null Valid	0.620	0.0156	0.682	0.0136	0.904	0.00913

	Wharton Land Regulation Index					
	(7)	(8)	(9)	(10)	(11)	(12)
	Duration	Replacement Rate	Duration	Replacement Rate	Duration	Replacement Rate
Revolving Unused Credit to Income	0.998***	0.131**				
	(0.301)	(0.0599)				
Total Unused Credit to Income			0.817***	0.108**		
			(0.238)	(0.0503)		
Credit Score					0.00248***	0.000324***
					(0.000481)	(9.43e-05)
Demographic Controls	Y	Y	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y	Y	Y
Lagged Earnings Controls	Y	Y	Y	Y	Y	Y
R2 First Stage	0.0690	0.0690	0.0841	0.0841	0.116	0.116
Angrist Pischke FStat Pval	0	0	0	0	0	0
Pval Weak Id Null Weak	0	0	0	0	0	0
Round N	19000	19000	19000	19000	19000	19000
Pval J test Null Valid	0.728	0.999	0.568	0.845	0.956	0.816

*Notes. Clustered standard errors at MSA level in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include lagged real annual earnings.*

Table 13: Correlation between Durations (in Weeks) and Unused Credit, Controlling for Assets (Source: 1998-2007 SCF)

	(1)	(2)	(3)	(4)	(5)	(6)
Unused Unsecured Limit to Income	12.334***	10.430***	8.733***	9.338***	8.155***	7.854***
	(5.85)	(4.87)	(4.02)	(4.31)	(3.75)	(2.66)
Year Dummies	N	Y	Y	Y	Y	Y
Demographics and Income	N	Y	Y	Y	Y	Y
Liquid Assets to Inc (Checking/Savings plus Stocks and Bonds)	N	N	Y	N	Y	Y
Illiquid Assets to Inc (Homes, Vehicles, etc.)	N	N	N	Y	Y	Y
Mortgagors Only	N	N	N	N	N	Y
Observations	764	764	764	759	759	421
R-squared	0.052	0.130	0.144	0.137	0.148	0.157

Notes: SCF 24 to 65yo Heads of Household with Positive Unemployment Spell over Prior 12 months and Positive Limit. Restrict to Mortgagors in Col 6. Demographics include quadratic in age, dummies for education, and dummies for race and Income refers to gross annual family income. Liquid Assets include cash, checking, money market funds, CDS, corporate bonds, government saving bonds, stocks, and mutual funds less credit card debt. Unused Credit Limit to Income refers to total credit card limits less credit card balances. Illiquid Assets includes Homes, Vehicles, Retirement, Annuities, Life Insurance at self-reported market values.

very little evidence of interstate movers or intrastate movers in our sample around job loss. If we drop movers, our IV regression results remain unchanged in terms of sign, significance, and magnitude.

C Proofs

Restatement of Proposition 6.1: *Assume that the utility function meets standard conditions ($u' > 0, u'' < 0, \lim_{c\to 0} u'(c) = \infty, \lim_{c\to\infty} u'(c) = 0$, and u is invertible), the matching function is invertible and constant returns to scale, and there is a bounded support (which can be non-binding) for the choice set of debt $b \in \mathbb{B} \subseteq [\underline{b}, \overline{b}]$ and the capital of firms $k \in \mathcal{K} \subseteq [\underline{k}, \overline{k}]$, then a Block Recursive Equilibrium exists.*

Proof. The proof will follow backward induction. Let $t = T$, and consider an unemployed household for the sake of brevity (an identical argument follows for employed households). Since the household's continuation value is zero from $T + 1$ onward, the household dynamic programming problem trivially does not depend on the aggregate distribution μ across states

Table 14: OLS with Direct Controls for House Prices (Source: LEHD/TransUnion 2002-2007)

Dep Var	(1) Duration	(2) Duration	(3) Replacement Rate	(4) Replacement Rate
Revolving Unused Credit to Income	0.0875***	0.0842***	0.0360***	0.0357***
	(0.0182)	(0.0182)	(0.00496)	(0.00499)
Demographic Controls	Y	Y	Y	Y
Industry Controls	Y	Y	Y	Y
MSA Controls	Y	Y	Y	Y
Lagged Earnings Controls	Y	Y	Y	Y
House Price Control	N	**Y**	N	**Y**
R-squared	0.050	0.050	0.078	0.078
Round N	19000	19000	19000	19000
R2 Adj	0.0479	0.0481	0.0767	0.0767

*Notes. Robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. Revolving Unused Credit to Income measured 1 year prior to layoff. Demographic controls include quadratic in age and tenure, race dummies, sex dummies, education dummies, presence of auto loans. Industry controls include 1-digit SIC dummies. MSA controls include real per capita GDP and the MSA unemployment rate. Lagged earnings controls include lagged real annual earnings. House Price control is OFHEO All Transaction MSA level house price index.*

in the last period of life,

$$\begin{aligned} U_T^G(b,h,k;\Omega) &= u(z(k)+b,1)+\beta\cdot 0 \\ &= U_T^G(b,h,k;y,\underline{b}) \end{aligned}$$

$$\begin{aligned} W_T^G(b,h,k;\Omega) &= u(\alpha f(y,h,k)+b,1)+\beta\cdot 0 \\ &= W_T^G(b,h,k;y,\underline{b}) \end{aligned}$$

In this last period of life, the saving and borrowing policy function $b'_{e,T}(b,h,k;y,\underline{b})$ is trivially zero (for both employed $e=W$ and unemployed agents $e=U$). Likewise, for households in bad standing in the last period of life, the value of unemployment (and nearly identical conditions hold for the employed, and so are omitted) is given by,

$$U_t^B(b,h,k;y,\underline{b}) = u(z(k),1)+\beta\cdot 0$$

Stepping back to the default decision, U_T will also not depend on the aggregate distribution μ,

$$U_T(b,h,k;y,\underline{b}) = \max\left\{U_T^G(b,h,k;y,\underline{b}),U_T^B(0,h,k;y,\underline{b})-\chi\right\}$$

Let $D_{U,T}(b,h,k;y,\underline{b})$ denote the policy function of the household. Since there is a utility penalty χ of defaulting, debt can be supported in equilibrium, and $D_{U,T}$ will **not** be trivially zero.

Now stepping back to the labor search problem, the firm's value function will be independent of μ as well,

$$\begin{aligned} J_T(h,k;\Omega) &= (1-\alpha)f(y,h,k) + \beta \cdot 0 \\ &= J_T(h,k;y,\underline{b}) \end{aligned}$$

And the labor market tightness will also be independent of μ,

$$\begin{aligned} \theta_T(h,k;\Omega) &= p_f^{-1}\left(\frac{\kappa + (1+r_f)k}{J_T(h,k;y,\underline{b})}\right) \\ &= \theta_T(h,k;y,\underline{b}) \end{aligned}$$

The household at age $T-1$ (note that the primes below simply note that age $T-1$ risk over y and $\underline{b}$ has already been realized and human capital has already evolved to h') must therefore make the following labor market search choice over k, the capital of firms,

$$\max_{k \in \mathcal{K}} \; p(\theta_T(h',k;y',\underline{b}'))W_T(b',h',k;y',\underline{b}') + \big(1 - p(\theta_T(h',k;y',\underline{b}'))\big)U_T(b',h',k;y',\underline{b}') \tag{5}$$

So long as k lies in a bounded interval, the extreme value theorem guarantees at least one solution to this problem. As we will see below, for certain classes of production functions, only one solution exists. For the current exposition, assume the production function lies within this class, and a unique solution exists.

Given the household policy functions for labor search $k'_{T-1}(h',k;y',\underline{b}')$ and default $D'_{e,T}(h',k;y',\underline{b}')$, the bond price $q_{U,T}(b',h,k;\Omega)$ is given by,

$$\begin{aligned} q_{U,T-1}(b',h,k;\Omega) &= \frac{\mathbb{E}\Big[1 - D_{e',T}(b',h',k';y',\underline{b}')\Big]}{1+r_f} \\ &= q_{U,T-1}(b',h,k;y,\underline{b}) \end{aligned}$$

Clearly the bond price does not depend on the aggregate distribution μ.

Stepping back from $t = T-1, \ldots, 1$, and repeating the above procedure completes the proof.

□

Restatement of Corollary 6.2: *Under the hypotheses of Proposition 6.1, so long as $\chi > 0$, and $\mathcal{B}$ contains a neighborhood of debt around 0, a Block Recursive Equilibrium with credit exists.*

Proof. Because of the inada conditions, for every positive $\chi \in \mathbb{R}_+$, there exists a sufficiently small debt in an ϵ-neighborhood around zero, $b \in N_\epsilon(0)$, such that the household strictly prefers repayment in the last period of life. The households repayment choice is given by,

$$\max\Big\{U_T^G(b,h,k;y,\underline{b}), U_T^B(0,h,k;y,\underline{b}) - \chi\Big\}$$

This holds with equality at the cutoff debt b^*,

$$U_T^G(b^*, h, k; y, \underline{b}) = U_T^B(0, h, k; y, \underline{b}) - \chi$$

Substituting,

$$u(z(k) + b^*, 1) = u(z(k), 1) - \chi$$

The minimum supportable debt is given by,

$$b^* = u^{-1}(u(z(k), 1) - \chi, 1) - z(k) < 0$$

□

Restatement of Lemma (6.3)***:*** *In addition to the assumptions in Proposition 6.1, let the production function be Cobb-Douglas, i.e.* $f(y, h, k) = yh^{1-a}k^a$ *(*$0 < a < 1$*), let the matching function be given by* $M(u, v) = u^{\frac{1}{2}}v^{\frac{1}{2}}$*, let* $\chi \to \infty$ *(no default for households), the value of leisure is zero, and assume there is no uncertainty over human capital* h*, aggregate productivity* y*, or the borrowing limit* $\underline{b}$*. Then if the utility function is negative, increasing, and concave (e.g.* $\frac{c^{1-\sigma}-1}{1-\sigma}$ *for* $\sigma > 1$ *or* $u(c) = -e^{-c}$*), the household labor search problem (equation (5)) admits a unique solution.*

Proof. The non-stochastic firm problem can be solved by hand, and under the hypotheses of the present lemma, it is directly proportional to capital,

$$J_t(h, k) = \frac{(1-\alpha)f(y, h, k)}{1 - \beta(1-\delta)} - \frac{(\beta(1-\delta))^{T-t+1}(1-\alpha)f(y, h, k)}{1 - \beta(1-\delta)} \propto k^a$$

Under the assumption $M(u, v) = u^{\frac{1}{2}}v^{\frac{1}{2}}$, the equilibrium market tightness $\theta_t(h, k)$ can be solved by hand.

$$\kappa = \theta_t(h, k; \Omega)^{-\frac{1}{2}}\left[J_t(h, k; \Omega) - (1 + r_f) \cdot \frac{k}{\theta_t(h, k; \Omega)^{-\frac{1}{2}}}\right]$$

Solving for θ_t yields,

$$\left(\frac{\kappa + (1 + r_f)k}{J_t(h, k; \Omega)}\right)^{-2} = \theta_t(h, k; \Omega)$$

The household job finding rate is therefore given by,

$$\left(\frac{J_t(h, k; \Omega)}{\kappa + (1 + r_f)k}\right) = p(\theta_t(h, k; \Omega))$$

For κ and r_f sufficiently small,

$$p(\theta_t(h, k; \Omega)) \propto k^{a-1}$$

The constant worker share α in combination with the non-negative and increasing production function implies that the wage a worker receives is concave and increasing in k. Note that the composition of two non-decreasing concave functions in k preserves concavity in k, i.e. $\tilde{u}(k) = u(w(h,k) + \mu)$ is concave in k for arbitrary μ. Let $\underline{u}$ be the outside option of the household if they remain unemployed. Since the probability of finding a job is directly proportional to k^{a-1}, the household chooses k to maximize

$$k^{a-1}\tilde{u}(k) + (1 - k^{a-1})\underline{u}$$

Since $-k^{a-1}$ is concave, we ignore the second term (the idea will be to show the first term is concave, and then use the fact that the sum of two concave functions is concave). The condition for the first term to be concave is given by,

$$\underbrace{(a-1)(a-2)k^{a-3}\tilde{u}(k)}_{(-)} + \underbrace{2(a-1)k^{a-2}\tilde{u}'(k)}_{(-)} + \underbrace{k^{a-1}\tilde{u}''(k)}_{(-)} < 0$$

Under the hypotheses that $u < 0$, $u' > 0$, $u'' < 0$ (note, these properties transfer to $\tilde{u}$), and $0 < a < 1$, the labor search problem of the household is strictly concave and one solution exists for k.

□

D Business Cycle Moments

Table 15 displays the business cycle moments for the main model in the text versus the data. The table makes the shortcomings of the model quite clear: the model is unresponsive to productivity shocks (Shimer [2005] and more recently Chodorow-Reich and Karabarbounis [2013]). Why does the Hagedorn and Manovskii [2008] calibration not work in this context? They noticed that the flow utility from non-employment must be large enough to make workers nearly indifferent between working and not working: workers then become sensitive to small movement in productivity and wages. It is impossible to make every type of worker indifferent between working and not working with significant heterogeneity and a constant unemployment benefit or flow utility of leisure. The only paper to our knowledge to address this issue is Lise and Robin [2013] who make the flow utility of non-employment a function of the workers type, the workers type squared, the aggregate state, and interactions between the workers type and the aggregate state. However, this type of data-fitting exercise lacks any sort of micro foundation. One alternate approach used by Christiano et al. [2013] to generate cyclical responses in the economy could be to squeeze firm surplus so that vacancy posting becomes very sensitive to small movements in productivity. However, since firms are heterogeneous as well, only the lowest type firm will be sensitive to productivity movements.

Table 15: Business Cycle Moments for Model During Main Simulation (1974 to 2012) vs. Data

Model							
x	u	v	θ	y	$\tilde{k}$	UE Rate	Default Rate
SD(x)/SD(y)	2.40	1.67	1.69	1.00	1.03	1.49	0.07
Autocorr(x)	0.67	0.44	0.79	0.83	0.80	0.35	-0.03
Corr(·,x)							
u_1	1.00	-0.14	-0.71	-0.67	-0.64	-0.85	0.05

Data							
x	u_1	v	θ	y	$\tilde{k}$	UE Rate	Default Rate*
SD(x)/SD(y)	9.50	10.10	19.10	1.00	-	5.90	6.07
Autocorrelation	0.94	0.94	0.94	0.88	-	0.91	0.92
Corr(·,x)							
u_1	1.00	-0.89	-0.97	-0.41	-	-0.95	0.55

Notes: HP filtered with smoothing parameter 10^5 to be consistent with Shimer [2005]. Data are from Shimer [2005], except (*) the default rate which is taken from Equifax (1999-2012). As in the data, u_1 is calculated as the fraction of unemployed households at the end of a quarter. $\theta = \frac{v}{u_1+u_2}$ includes the measure of households that immediately found jobs (u_2), hence the low volatility as that mass is quite large and very stable.

E Model Robustness: Capital Investment and Liquidation

E.1 Model with Firm Investment

Now assume that Firms can invest in capital, depending on the worker's type. The problem of an unemployed household is unchanged. The value functions for employed borrowers who default as well as the discrete default decision are formulated in an identical fashion to that of the unemployed.

Timing assumption: New capital is not operable immediately.

As a result, the Bellman equation for a household in bad standing is given below (good standing is extremely similar):

$$
\begin{aligned}
W_t^B(b,h,k;\Omega) = u(c,0) + \lambda\beta\mathbb{E}\Big[&(1-\delta)W_{t+1}(0,h',\mathbf{k'};\Omega') \\
&+ \delta\Big\{\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}(0,h',\tilde{k};\Omega') \\
&\qquad + \big(1-p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}(0,h',\mathbf{k};\Omega')\Big\}\Big] \\
&+ (1-\lambda)\beta\mathbb{E}\Big[(1-\delta)W_{t+1}^B(0,h',\mathbf{k'};\Omega') \\
&+ \delta\Big\{\max_{\tilde{k}} p(\theta_{t+1}(h',\tilde{k};\Omega'))W_{t+1}^B(0,h',\tilde{k};\Omega') \\
&\qquad + \big(1-p(\theta_{t+1}(h',\tilde{k};\Omega'))\big)U_{t+1}^B(0,h',\mathbf{k};\Omega')\Big\}\Big], \quad t \le T
\end{aligned}
$$

$$W_{T+1}^B(b,h,k;\Omega) = 0$$

Such that the aggregate laws of motion are given by equation (1), human capital evolves such that $h' = H(h,W)$ and the budget constraint is given by,

$$c \le \alpha f(y,h,k)$$

And, additionally

$$k' = k_t^{*'}(h,k;\Omega)$$

This final condition $k' = k_t^{*'}(h,k;\Omega)$ means that households have rational expectations over what the entrepreneurs's optimal investment decision is.

E.2 Lenders

Lenders' bond prices are update to reflect changes in capital, since it may affect the wage of the worker and hence their repayment probability.

E.3 Entrepreneurs

We now allow entrepreneurs to invest in capital subject to an adjustment cost $\Gamma(k' - k)$. Therefore the value function for the firm is given by,

$$J_t(h, k; \Omega) = \max_{k'} (1 - \alpha) f(y, h, k) - i - \Gamma(k' - k) - f_c + \beta \mathbb{E}\big[(1 - \delta) J_{t+1}(h', k'; \Omega')\big]$$

Subject to a unit investment cost (i.e. the MRT of output and capital is 1, excluding the adjustment cost),

$$i = k' - k$$

$$J_{T+1}(h, k; \Omega) = 0$$

In the results below, we choose a quadratic adjustment cost $\Gamma(x) = x^2$. We see that the presence of firm investment does not significantly alter the main set of results.

Figure 10: Allowing for Capital Investment: Employment

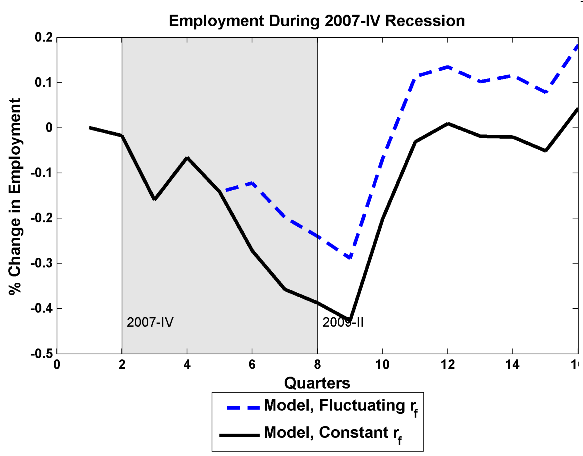


Figure 11: Allowing for Capital Investment: Corr. B/w Human Capital (h) and Firm Capital (k)

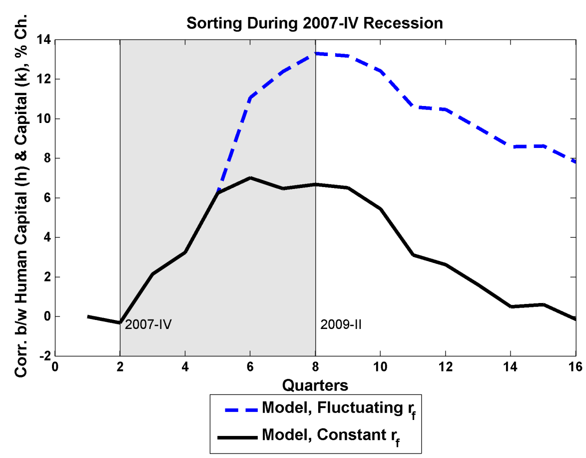


Figure 12: Allowing for Capital Investment: Agg. Firm Capital, 2007-2009 Recession

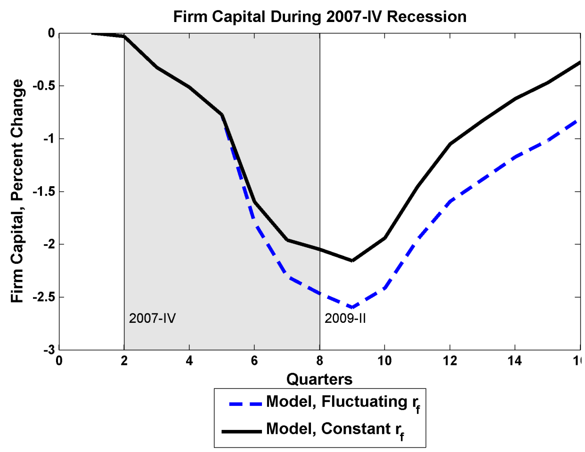
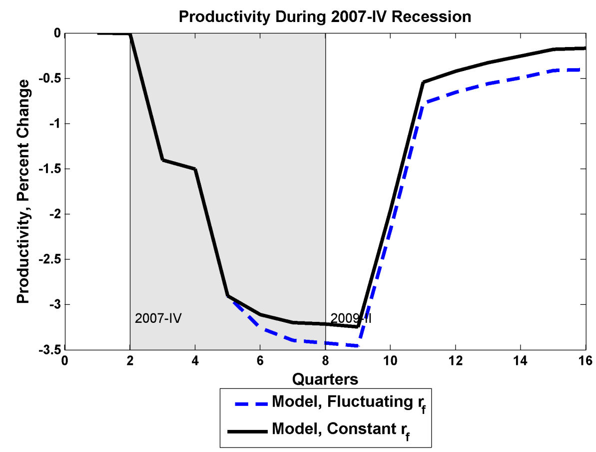


Figure 13: Allowing for Capital Investment: Labor Productivity, 2007-2009 Recession



E.4 Liquidation

We also allow for the baseline model to have a liquidation value of capital, χ_f. The continuation value of the firm becomes,

$$J_t(h,k;\Omega) = (1-\alpha)f(y,h,k) - f_c + \beta\mathbb{E}\big[(1-\delta)J_{t+1}(h',k;\Omega') + \delta\chi_f k\big]$$

In the results below, we choose $\chi_f = .1$ to preserve the calibration, approximately. Small perturbations of the liquidation value leave the baseline model's results unchanged. Larger perturbations require recalibration. Figures 14 and 15 illustrate the model's main results with liquidation values. Employment rises, while productivity falls in both cases. The magnitudes of the impact of a tighter debt limits are unchanged.

E.5 Interest Rate Experiment

In this section, we conduct an experiment designed to mimic monetary policy, where the risk free rate falls from 4% to 0% in 2008-Q1. Each plot contains three lines that correspond to different sectors of the economy receiving interest rate reductions:[43]

i. **Model, r_f Constant**: The solid black line corresponds to the constant risk-free rate economy.

[43] The parameters used in this study are slightly different from the main text, and are based on a prior calibration. $p_{-\Delta}$= 0.139, z= 0.097, f_c= 0.098, κ= 0.042, η= 0.260, β= 0.990, χ= 0.878, $p_{+\Delta}$= 0.070. All other parameters are the same

Figure 14: Liquidation Value Experiment: Agg. Firm Capital, 2007-2009 Recession

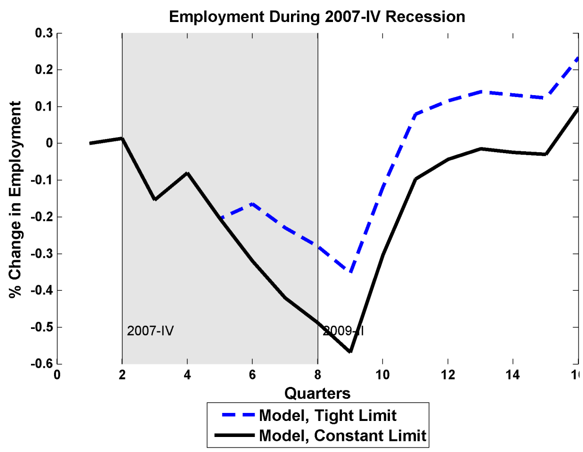
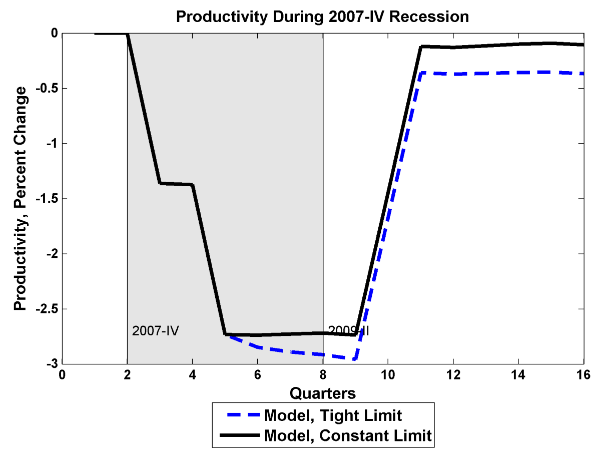


Figure 15: Liquidation Value Experiment: Labor Productivity, 2007-2009 Recession



ii. **Model, r_f Decr. for Household (HH) Debt, HH Saving, and Entrepreneur Debt**: The dashed blue line corresponds to the economy in which interest rates fall across the board – for households that save, for households that borrow, and for firms. This is the main experiment.

iii. **Model, r_f Decr. for Household (HH) Debt Only**: Since there are multiple mechanisms operating in the model when the risk free rate falls, we plot the outcome of an additional experiment which illustrates the pure effect of easing household borrowing constraints. We let the interest rate on household (HH) debts decline while we hold constant the risk free rate that savers face and that firms face; this is given by the red, dash-dot line.

Figure 16 illustrates the path for productivity and interest rates. We find that the reduction in interest rates induces a sorting inversion. In the experiment, however, standard sorting metrics actually *deteriorate* when the risk-free rate is reduced (Figure 17). The mechanism is that the reduction in risk-free rates makes low-human-capital-borrowers richer, allowing them to match with firms that have greater amounts of physical capital, whereas the reduction in risk-free rates makes high-human-capital-savers poorer, forcing them to match with firms that have lesser amounts of physical capital. More colloquially, when interest rates fall, "bad" workers match with "good" firms, and "good" workers match with "bad" firms, so there is a sorting *inversion*. The reason output increases, even though sorting declines, is that credit-constrained firms are able to post more vacancies with greater amounts of capital (Figure 18). As a result, Figure 19 shows that there is more capital per worker (even though sorting falls), and therefore measured labor productivity (output over employment) increases by about $\frac{1}{10}$%. Figure 20 shows that the household channel tends to depress employment, while the firm channel (which leads to more vacancies per unemployed HH, see Figure 21) tends to increase employment. The net effect is that interest rate reductions boost employment.

Figure 16: Drop in r_f Experiment: Exogenous Aggregate Productivity (y) and Risk Free Rate (r_f), 2007-2009 Recession

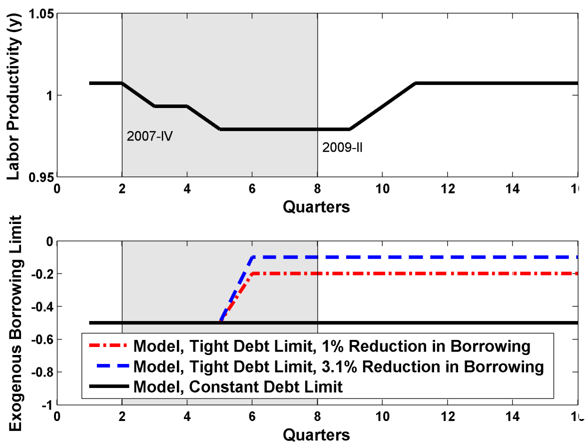


Figure 17: Drop in r_f Experiment: Correlation Between Human Capital (h) and Firm Capital (k)

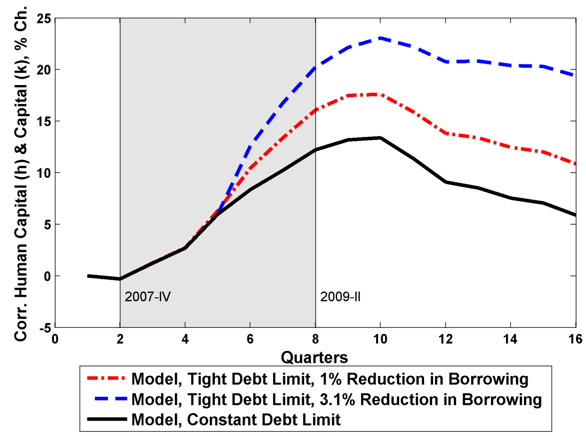


Figure 18: Drop in r_f Experiment: Agg. Firm Capital, 2007-2009 Recession

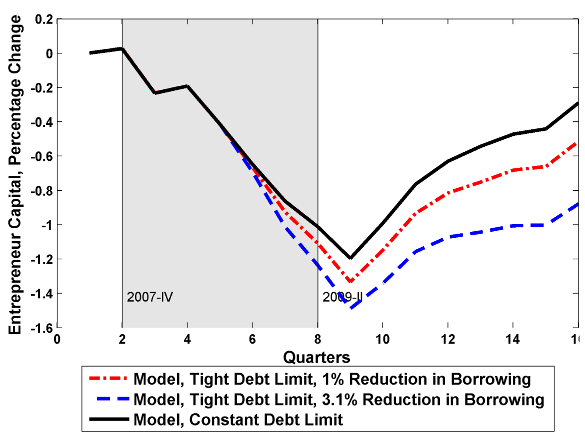


Figure 19: Drop in r_f Experiment: Labor Productivity, 2007-2009 Recession

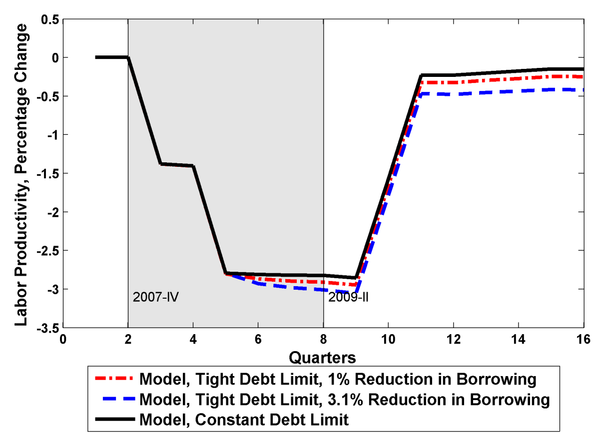


Figure 20: Drop in r_f Experiment: Employment, 2007-2009 Recession

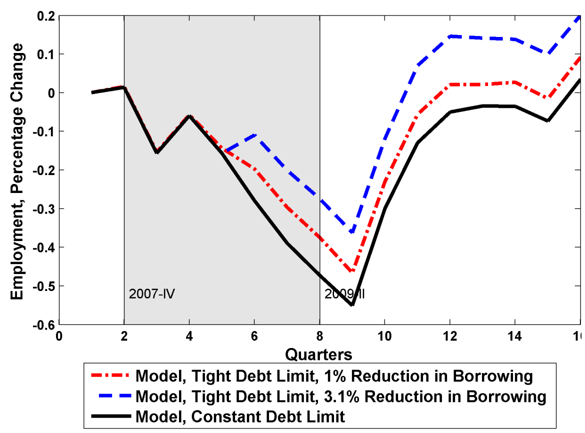


Figure 21: Drop in r_f Experiment: Market Tightness, 2007-2009 Recession