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Financial Constraints in Search Equilibrium: Mortensen and Pissarides Meet Holmstron and Tirole

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Abstract
The Great Recession has indicated that firms' leverage and access to finance are important for hiring and firing decisions. It is now empirically established that bank lending is correlated to employment losses when credit conditions deteriorate. We provide further evidence of this drawing on a new dataset that we assembled on employment adjustment and financial positions of European firms. Yet, in the Diamond Mortensen Pissarides (DMP) model there is no role for finance. All projects that display positive net present values are realized and financial markets are assumed to be perfect. What if financial markets are not perfect? Does a different access to finance influence the firm's hiring and firing decisions? The paper uses the concept of limited pledgeability proposed by Holmstrom and Tirole to integrate financial imperfections and labor market imperfections. A negative shock wipes out the firm's physical capital and leads to job destruction unless internal liquidity was accumulated by firms. If firms hold liquid assets they may thus protect their search capital, defined as the cost of attracting and hiring workers. The paper explores the trade-off between size and precautionary liquidity holdings in both partial and general equilibrium. We find that if labor market frictions disappear, so does the motive for firms to hold liquidity. This suggests a fundamental complementarity between labor market frictions and holding of liquid assets by firms.

Keywords: search frictions, financial frictions, leverage, liquidity, pledgeability
JEL codes: G01; J64

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1 Introduction

The 2008 financial crisis and the associated increase in unemployment on both sides of the Atlantic sparked a new interest in the relationship between financial imperfections and labor market dynamics. In the aftermath of the crisis, a growing empirical literature studied the links between financial conditions and employment adjustment. The Great Recession has indicated that firms' leverage and firms' access to finance are clearly correlated to hiring and firing decisions. More specifically, it is now empirically accepted that frictions in bank lending are correlated to employment losses when credit conditions deteriorate.[1]

The Diamond Mortensen Pissarides (DMP) model is the main paradigm for addressing imperfect labor markets. In the baseline framework, there is no role for finance. All projects that display positive net present values are realized and financial markets are assumed to be perfect. What if financial markets are not perfect? Does a different access to finance influence the firm hiring and firing decisions? These basic questions call for a deeper understanding of the relationship between labor and finance. Among the financial frictions addressed by the literature and reviewed below, this paper exploits the concept of limited pledgeability proposed by Holmstrom and Tirole (2011). The idea is that only part of the entrepreneur's income is pledgeable and can be borrowed upon, either because part of the income is private benefit or because the entrepreneur needs incentives. By adding financial imperfections and borrowing constraints into an otherwise standard equilibrium unemployment model, the paper contributes to the building of an archetype and flexible model of labor and finance.

In our model, firms are financially constrained by limited pledgeability, invest in physical capital, and hire workers within an imperfect labor market. Entering firms attract workers by posting vacancies with wages attached to them, and hire up to an endogenously determined size level that depends on the firms' access to finance. Firms anticipate the possibility that new funding will be needed over the lifetime, and that refinancing may not be available in those times. If that happens, the firm must rely on liquid assets for financing the rebuilding of its physical capital. In the absence of such funds, the firm is forced to fire workers and close down its operations. When workers are fired, the firm loses its *search capital*, defined as the cost of attracting and hiring workers. *Ex ante*, firms therefore face a trade-off between investing their limited funds in liquid assets to protect their search capital, or to invest in more capacity and more employees.

Our theoretical model shows that if labor market frictions disappear, so does the motive for firms to hold liquid assets. This implies a fundamental complementarity between labor market frictions and holding of liquid assets by firms that is novel in the literature. In this sense, the paper brings together the work on liquidity by Holmstrom and Tirole (2011) with the traditional Mortensen Pissarides (1994 and 1999) model of equilibrium unemployment.

While we largely exploit the concept of limited pledgeability, other financial frictions have been proposed in the literature. First, there exists an early literature, prior to the 2007 financial crisis. In such early papers, Greenwald-Stiglitz (1993) looked at the risk aversion of firms. Farmer (1985) studied the financing of quasi-fixed costs, and Townsend (1979) proposed the costly verification model. Sticky bank borrower relationships also emerge in the context of asymmetric information with moral hazard (Holmstrom and Tirole, 1997) and adverse selection (Sharpe, 1990). In a macro labor literature that emerged after the financial crisis, Christiano et al. (2015) looked at the real effects of borrowing spreads while Hall (2014) and Keho et al. (2014) looked at the labor market impact of schocks to consumers and firms' discount rate.

Within the DMP-labor-finance literature, the pioneering work was Wasmer and Weil (2004) in-

[1] Chodorow-Reich (2014) and Bentolila et al. (2014) use loan level data for the US and Spain during the 2007/09 financial crisis to identify the effects of banks health on employment changes; Boeri, Garibaldi and Moen (BGM, 2013) review the empirical literature and provide new evidence using macro, sectoral and firm-level data. Pagano and Piga (2010) use sectoral data to identify the impact of leverage on employment changes, using the methodology proposed by Rajan and Zingales (1998) to study the relationship between finance and growth.

vestigation of the interplay between matching frictions in both the labor and the financial markets. Merz and Yashiv (2007) discussed the relationship between adjustment costs of labor and the value of the firm. Michelacci and Quadrini (2009) analysed the effects of financial market imperfections on employment adjustment, and the size distribution of firms. Kueh et al. (2012) integrated search theory with asset pricing. Finally, there is a growing set of papers studying the links between finance and labor market volatility within the DMP framework. Eckstein et al. (2014) look at the real effects of borrowing spreads. Petrosky-Nadaeu and Wasmer (2013) study the dynamic effects and volatility effects of the double frictions á la Wasmer and Weil. Petrosky-Nadaeu (2014) looks at the financial frictions in the vacancy costs. Garin (2015) and Iliopolus et. al. (2015) investigate the effects of shocks to collateral in a Kiotaky and Moore (1997) fashion. Boeri-Garibaldi and Moen (2015) study the interplay between limited pledgeability, job creation and business cycle volatility within the DMP framework.

The structure of the paper is as follows. Section 2 presents some of the key empirical regularities between access to credit and employment changes using micro data on firms' balance sheets and employment variations over the Great Recession. Section 3 introduces the model, and characterizes the financial decision of the firm in partial equilibrium. Section 4 derives the general equilibrium results. Extensions are provided in section 5, while section 6 discusses the key findings of our theory in a broader perspective. Finally, section 7 concludes.

2 Some facts about access to finance and employment

This section presents some empirical regularities on the relationship between financial conditions and employment variations of firms.

Specifically, we present facts based on on a dataset of firm-level employment adjustment and leverage during the Great Recession. The data cover the period 2007-9 and are obtained by matching data from the EFIGE survey of European firms with information from balance sheets obtained in the Amadeus archive. Efige samples some 16,000 European firms (3,000 in large countries, such as Germany, France, Italy, Spain and the UK, and 500 firms in smaller countries, such as Austria and Hungary). The data in the matched sample cover mainly medium-sized and large firms (the average firm size in terms of employees is 81).[2]

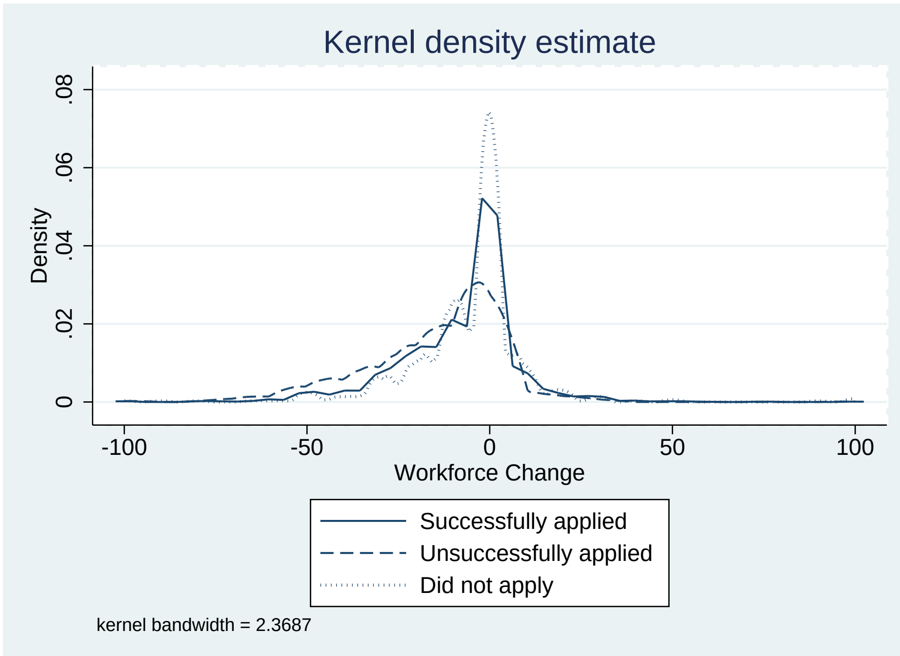
Our main variable of interest is employment changes.[3] In the statistical annex, we plot the distribution of employment changes using a Kernel density estimator. As our data cover the Great Recession, most firms appear to be downsizing.

To summarize regularities and insights as to the importance of finance in employment adjustment, Figure 1 plots the Kernel estimates for firms that successfully applied for credit (continuous line), as well as firms that did not apply for credit (dotted line) or that applied, but were not successful (dashed line). The distribution of job losses among those that unsuccessfully applied for credit lies strictly above the other two distributions. This suggests that the firms that were unsuccessful in refinancing operations were, on average, heavily downsizing (on average by almost 20 %) while the distribution of employment adjustment among successful debtors and firms that did not apply for credit is remarkably similar (in the latter group there is only a larger proportion of firms not experiencing employment variations). The concentration of employment losses (about 30 per cent of the total) among firms experiencing difficulties in refinancing operations is obviously not informative as to causality: it may well be that firms did not obtain credit because they were downsizing and considered not viable by

[2]The questionnaire is very detailed on a number of structural characteristics of firms such as organization, job composition, innovation activities, finance as well as product and labor market strategies. The Amadeus archive provides financial and business data on Europe's biggest 500,000 companies by assets.

[3]We draw on the following question asked to employers at the beginning of 2010: *During the last year (2009) did you experience a reduction or an increase/decrease of your workforce in comparison with 2008?* . For those stating to have changed employment levels, a second question elicited the percentage change in the workforce. We imputed a zero value to firms declaring that they did not experience any change in employment in the first question

Figure 1: Firm-level net employment change, distribution of firms by access to credit



banks. Yet, the figure clearly reports a link between access to credit and employment changes, as we summarize in the following.

- **Fact 1** Job losses are negatively correlated with access to credit during the financial crisis

In addition to employment changes, we exploit measures of leverage in 2007, the year before the beginning of the Great Recession. In particular, the *Gearing ratio* is the debt to equity ratio measuring the extent to which the firm is using creditor's vs. owner's funds, whilst the *solvency* ratio measures the ratio of after tax net profit (excluding non-cash depreciation expenses) over debt and is a measure of one company's ability to meet long-term obligations. The statistical annex reports some descriptive statistics on those data.

To correlate financial leverage to employment changes controlling for firm characteristics, we estimate a regression of changes in employment on firm, sector and aggregate country fixed effects, output variations as well as leverage. In particular, Table 1 reports estimates of the following equation

$$\Delta e_{ijc} = \alpha + \alpha_j + \alpha_c + \alpha_j * \alpha_c \beta \Delta y_{jc} + \gamma Lev_{ijc} + \delta S_{ijc} + \epsilon_{ijc} \tag{1}$$

where Δe is the reported employment growth rate *during* the period 2008-9, i denotes the firm, j the sector and c the country, S is a set of size dummies (employment or turnover) and Lev is the Gearing Ratio, measured *before* the Great Recession (according to 2007 balance sheet data). Δy_{jc} is change in the sectoral output. We also include country and sector dummies as well as interactions between the two sets of dummies. We summarize these results in our second empirical regularity.

- **Fact 2** Financial leverage is negatively correlated to net employment changes during the crisis

Fact 2 is reported in Columns (1) and (2) in Table 1. The dependent variable is employment change. The gearing ratio is negatively associated with plant-level employment change, while the Solvency Ratio is positively associated with employment changes.

While these correlations are significant, leverage is clearly endogenous. The growing empirical literature that has used the Great Recession as an episode of credit contraction is concerned with the causal effect of credit contraction on employment. Chodorow-Reich (2014) for the U.S. and Bentolila et al. (2014) for Spain looked at the health conditions of banks during the crisis as a way to identify the shock to credit independently of the firm conditions. They both found evidence of a *causal effect of credit disruption on employment losses*. We use our dataset to see whether we can confirm the presence of a causal effect of leverage on job losses during a financial crisis.

Columns (3) to (6) of Table 1 display 2-stages least squares estimates in which leverage is instrumented by a dichotomic variable capturing firms that can use third party collateral being part of a consortium of firms. The underlying identification assumption is that the presence of this collateral affects the (equilibrium) level of leverage prevailing before the financial crisis while it does not directly affect employment variation during the Great Recession. The first-stage results point to a significant and positive (negative) effect of third party collateral on leverage (solvency). Access to third party collateral increases the probability that firms can draw on external finance. To the extent that a firm is part of a consortium of firms offering third party collateral, we expect this firm to face lower costs of borrowing and, ceteris paribus, be more leveraged than firms not being part of consortia of this type. There is an extensive literature in finance supporting this hypothesis[4] , and our first stage results indicate that indeed leverage is positively affected by access to third party collateral. True that involvement in consortia of firms, in addition to capital mobility, may also involve labor mobility within the consortium of firms. However, labor is less mobile than capital, and it is particularly less so under a generalized shock like a recession. Thus, the possibility to absorb shocks via reallocations of workers across firms in the consortium is limited. Notice further that our regressions include size and sector dummies as well as interactions between the two, capturing potential key factors of heterogeneity across firms.[5]

In the second stage we still find a negative and statistically significant effect of leverage and solvency on firm-level employment adjustment. The effects of leverage on employment adjustment is non-negligible: bringing, say, a typical Austrian firm to the average gearing ratio of a German firm involves additional employment losses of the order of 3 per cent during a financial recession; increasing by 10 basis points the solvency ratio (like moving an average Italian firm to France) involves a 6 per cent increase of employment.[6]

This confirms the following empirical regularity.

- **Fact 3** Financial leverage negatively affects employment changes during the crisis

Where do the effects of leverage on job losses come from? Columns (5) and (6) display estimates of equation (1) when only firms downsizing or only firms upsizing are considered. The focus is on leverage, but the results are the same when we consider solvency ratios. They suggest that after the financial crisis the effect of leverage on firm-level employment adjustment is driven by firms that are downsizing. For upsizing firms the second-stage coefficient is negative, but not statistically significant[7]. Thus, we have

[4]See, for instance, the 2010 special issue on partial credit guarantees of the Journal of Financial Stability.

[5]Access to third party collateral is generally unrelated to individual firm's characteristics, as membership of the consortia depends on the sectoral or regional affiliation of the firm. However, in some countries membership of the consortium may be based on the screening of the applicants, and potentially on characteristics which are themselves correlated with employment variation over the Great Recession. To the extent that these consortia are typically devices allowing firms to improve their access to capital markets, they confine access to firms that are in rather good financial conditions, as the other members perceive the negative externalities that could be exerted over the entire consortium by firms in financial distress. We expect firms in bad financial conditions to have downscaled during the Great Recession. Hence selection of firms into the consortia based on good financial conditions would work against our results.

[6]As shown by the bottom row of Table 7, the 2SLS estimates have substantially less observations that the OLS estimates. This is because there are many missing values in the question about third party collateral. We did run regressions replacing missing values with 0, but did not find substantial differences

[7]We also run regressions including firm-level output growth (rather than the average growth rate at the sectoral level) as right-hand-side variable. Such a specification clearly creates a problem of endogeneity, but potentially cap-

Table 1: Leverage and Employment Adjustment

	(1)	(2)	(3)	(4)	(5)	(6)
Variables	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$
Sample	All firms	All firms	All firms	All firms	Downsizing	Upsizing
Method	OLS	OLS	IV	IV	IV	IV
Second stage						
$\Delta \bar{y}$	1.11	1.05	-57.31	98.56	95.87	33.53
	(0.910)	(0.901)	(133.3)	(169.1)	(132.8)	(679.9)
Gearing	-0.01***		-0.03**		-0.34*	-0.03
	(0.00)		(0.01)		(0.02)	(0.17)
Solvency		0.04***		0.60***		
		(0.01)		(0.21)		
Constant	-8.12***	-10.73***	-13.09	-13.19	-24.75	0.98
	(2.59)	(2.63)	(17.11)	(20.69)	(16.62)	(106.20)
Country	YES	YES	YES	YES	YES	YES
Sector	YES	YES	YES	YES	YES	YES
Country*Sector	YES	YES	YES	YES	YES	YES
Size	YES	YES	YES	YES	YES	YES
First stage						
			Gearing	Solvency	Gearing	Gearing
Third party collateral			108.24***	-6.85***	88.37***	31.11***
			(16.48)	(1.69)	(21.31)	(68.12)
Observations	8596	9649	2358	2900	1195	307

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

- **Fact 4** The effects of financial leverage on employment changes during a financial crisis are concentrated in downsizing firms.

Overall, our results suggest that leverage matters for employment adjustment during a financial recession, and operates mainly along the gross job destruction margin. Ceteris paribus, more leveraged firms destroy more jobs than firms with a higher solvency ratio.

3 Model

Our starting point is a directed search model of the labor market, where entrepreneurs pay a fixed cost of entry and may potentially hire many workers in a labor market with frictions, and where the initial investments are financed by borrowing in an imperfect financial market. This section goes through the building blocks of the theory. First, we describe in some details the environment, and the timing of the model. In section 3.2 we focus on the labor market friction and the search process. Section 3.4 describes the financial contract while section 3.3 presents the asset value equations. Section 3.5 presents the financial decision in partial equilibrium. General equilibrium and the key propositions are derived in section 4.

tures idiosyncratic shocks unrelated to the financial recession. Also in this case, there is still an effect of leverage on employment growth. As a further robustness check we run regressions putting on the left-hand-side a categorical variable (0 for downsizing, 1 for firms keeping the same employment level, 2 for those upsizing) in order to cope with measurement error, notably heaping in the reporting of employment adjustment. There is still a statistically significant effect. Coefficients are remarkably stable across these different specifications

3.1 The environment

We study a model of risk neutral workers and firms, who discount the future at the same rate r. There is mass one of a infinitely lived workers. Entrepreneurs set up firms, finance their investment in a credit market with frictions, and hire workers in a labor market that also contains frictions. As there is free entry of firms, the supply of entrepreneurs is infinitely elastic.

Entrepreneurs set up a firm at cost F. We assume that F is an effort cost, and hence does not need financing. Then entrepreneurs invest in A units of capacity (A machines), where A is decided endogenously by the firms. The unit cost of capacity is normalized to 1. The maximum capacity of firms is irreversible and cannot be increased later on. The production technology is Leontief in workers and machines, hence the firm hires A workers. Output is linear in the number of jobs with marginal productivity equal to y, so that the total output is $f(A) = yA$. The workers stay with the firm until their job is destroyed.

After the workers are hired, a firm produces until it is hit by a negative shock, which arrives at probability rate λ. We refer to this as a λ-shock. The shock destroys the machines, and makes all contracts void. The firm, if it gets refinancing, can reinvest, buy new machines, and retain the workers. If it does not get refinancing, it has to rely on its own internal financial resources for reinvestments. If production continues, the wage contracts are renegotiated, and in this renegotiation game the firms have all the bargaining power. Hence, after refinancing, the employees will receive their outside option. This assumption will be relaxed in section 5 when we study the effects of wage renegotiations after the shock..

The process of matching vacant jobs to unemployed workers is characterized by a standard aggregate matching function. Firms post costly vacancies to attract workers. Attached to each vacancy, the firm posts a present discounted wage of W. In this sense, our model is coherent with the competitive search specification a-la-Moen. Search is directed, and firms maximize profits given the life-time value of unemployment, U. As will be clear below, firms attract workers immediately by paying an upfront search cost. In this respect, the specification and characterization of the search process used in our paper is coherent with the fixed cost approach taken by Blanchard and Gali (2010), and represents a microfoundation of their assumption in terms of competitive search.

The entrepreneurs have no financial wealth of their own, and finance their investments through credit. The entrepreneurs receive an exogenous income flow y_0, independently of production levels. In addition, they obtain income by the production process. As in Holmstrom and Tirole, the financial friction in our model is that an entrepreneur cannot commit to repay her entire future income obtained by the production process. More specifically, we assume that the entrepreneur can commit to repay her exogenous income y_0 (the private income which is necessary in order to get any borrowing at all) plus a fraction strictly less than one of the income the project is expected to generate. There may be several reasons why the entrepreneur cannot borrow on the entire future income flow. First, part of the gain from running a business may be a private, non-pecuniary, benefit which cannot easily be transferred to the creditor. Second, in order to provide incentives to the entrepreneur to make the right decisions, taking properly care of the machines and so on, the entrepreneur must have a sufficiently large stake in the project. We refer to the part of the income that the entrepreneur can commit to repay as the entrepreneur's pledgeable income.

The time horizon of the initial contract with the financier is up to the point where the λ-shock hits. At this point, the machines are gone, and the contracts are void.[8] Hence, at the point of firm creation, the firm cannot borrow on incomes (neither y_0 nor the output flow) that accrue after the shock.

A key feature of our model is that the firm may want to build financial reserves prior to the λ-shock in order to be able to self-finance the reinvestment costs if it cannot get refinancing through the financial system. The size of the financial reserves is denoted I, $I \leq A$. The financial reserves are

[8]Technically speaking, the collateral is the income flow from the machines, not the machines themselves. However, the income flow is gone when the machines are destroyed by the λ shock.

liquid assets. They may consist of cash, treasuries or liquid stocks. Potentially, even real estate could be considered, even though we prefer to think of I in terms of financial assets.[9] In order to simplify the exposition, and avoid tedious and complicated tracking of the the accumulated interests on the reserves when the λ-shock hits, we assume that the firm places the assets I at an intermediary. The intermediary promises to pay the firm an amount I when the λ-shock hits, at an *ex ante* cost of $\tilde{\lambda} I$, where $\tilde{\lambda} = \lambda/(r+\lambda)$.[10]

To summarize, the life cycle of a firm is as follows:

1. The entrepreneur sinks a fixed effort cost F in order to create the firm.
2. The entrepreneur signs a contract with a financial intermediary, and invests in machines A and financial assets I.
3. Job creation and hiring take place.
4. The firm produces until a λ-shock hits. The shock destroys the machines, and renders all contracts void, and the firm has to reinvest in new machines.
   (a) With probability $1-\tau$, the firm gets refinancing. A new machines are bought at full cost, and workers are retained and paid their outside option that we indicate with U.
   (b) With probability τ, the firm does not get refinancing. The firm uses its financial reserves to buy $I \leq A$ machines at full cost. I workers are retained, and $A - I$ worker are displaced. Both the displaced and retired workers get their outside options U.
5. The firm continues to produce until a second adverse λ shock concludes the life of the firm.

3.2 Search

Employees are costly to acquire due to search frictions. Gali and Blanchard (2010) assume that firms attract workers immediately, but have to pay a hiring cost per worker equal to $C()$, where C is a function of aggregate variables that each firm takes as given. With financial frictions, it is convenient that firms attract workers without a time lag. We will now show how this can be obtained endogenously in a way that is fully coherent with the Diamond-Mortensen-Pissarides framework, by allowing firms to post many vacancies per job slot. Furthermore, the hiring cost C will only be a function of U, the expected net present value of the future income flow of an unemployed worker.

We assume that search is competitive (Moen (1997), Shimer (1996), and Mortensen and Wright (2002)).[11] At the aggregate level, a constant return to scale matching function $x(u,v)$ maps the stocks of searching workers u and firms with vacancies v into a flow x of new hires. To simplify some of the expressions we assume that the matching function is Cobb-Douglas, i.e., that $x(u,v) = u^{\beta} v^{1-\beta}$. Let $p(\theta)$ denote the job finding rate of searching workers and $q(\theta)$ the arrival rate of workers to searching firms, where $\theta = v/u$ is labor market tightness.

A firm i posts v_i vacancies, and each vacancy comes with a rent $R_i = W_i - U$, where W_i is the net present value of the future income flow of a worker hired in firm i. The firm can post as many vacancies as it wants at cost c per vacancy. The instantaneous probability rate of finding a worker when v_i vacancies are posted is $v_i q(\theta)$, where θ depends on the rent R_i offered. Since the expected

[9] In section 6 we discuss the empirical evidence on firm liquidity around the Great Recession.

[10] To see that this is a fair price, note that

$$\begin{aligned} r\tilde{\lambda} I &= \lambda(I - \tilde{\lambda} I) \\ \tilde{\lambda} &= \frac{\lambda}{r+\lambda} \end{aligned}$$

[11] For a large-firm application (as in the present paper) see Garibaldi, Moen and Sommervold (2015) and Kaas and Kircher(2013).

time to fill a single vacancy when the firm has v_i vacancies open is $\frac{1}{v_i q(\theta)}$, the time necessarily to fill a vacancy tends to zero as v becomes infinitely large. Furthermore, as the value of a filled job exceeds the expected search cost (this must be true in equilibrium, since the firm has to capitalize the fixed cost F), the firm has an incentive to post as many vacancies as possible. As v_i goes to infinity, the flow cost γv_i also goes to infinity. In the limit, the worker is obtained immediately, hence we can ignore discounting. The search cost per worker is thus equal to $\lim_{v_i \to \infty} \frac{\gamma v_i}{q(\theta) v_i} = \frac{\gamma}{q(\theta)}$. In words, this means that as v_i goes to infinity, the firm receives a worker immediately at search cost $\gamma/q(\theta)$.

From a worker's standpoint, the rent R and the job finding probability $p(\theta)$ are connected through the life time value of unemployment, as

$$rU = z + \theta q(\theta) R \tag{2}$$

where R is the equilibrium worker rents offered by firms. In equilibrium, workers receive the same expected income independently of which firms they search for, so that $R_i = R$, where R_i is the rent offered by firm i. The relationship between θ and R into equation (2), is akin to a unemployed indifference curve, and highlights the workers' tradeoff between R and market tightness θ.

We define hiring cost for the firm as the costs associated with employing the worker, over and above his opportunity cost rU of working in the firm. Total hiring cost in firm i is thus $A(\gamma/q(\theta) + R_i)$, and total hiring cost per worker is $C = \gamma/q(\theta) + R_i$.[12] As will be clear below, the firm has an incentive to minimize total hiring cost per worker, and hence solves the problem

$$C = \min \left[\frac{\gamma}{q(\theta)} + R_i \right] \qquad \text{S.T.} \qquad rU = z + \theta q(\theta) R \tag{3}$$

Total hiring cost per worker is a function of U, and we write $C = C(U)$. Below we refer to $C(U)$ as the *search capital* associated with having one worker on board. In the the theoretical annex we show that the total hiring cost function is

$$C(U) = \frac{\gamma}{q} \frac{1}{1-\beta} \tag{4}$$

where

$$\theta(U) = \frac{rU - z}{\gamma} \frac{1-\beta}{\beta}$$

It follows that $C'(U) > 0$ and $\theta'(U) > 0$. With a Cobb-Douglas matching function, one can show that $C''(U) < 0$.

Another issue is the time profile of wages. We assume that the worker is paid a fixed wage $\overline{w}$ up to the λ-shock hits. The fixed wage is given by

$$\overline{w} = rU + (r + \lambda) R \tag{5}$$

which gives an expected rent of R. Alternatively, the firm could pay the entire rent upfront. As will be clear shortly, the time profile of the wage up to the λ shock is irrelevant, even in the presence of financial frictions.

3.3 Asset values

Let $M(A, I)$ denote the joint present discounted value of revenues obtained by a firm of size A with financial resources I. Since wage payments are a transfer between the firm and the workers, they do not enter in the joint income. Furthermore, recall that the worker after a λ-shock obtains his outside option, independently of whether he is retained or fired. The asset value equation for joint present discounted income, $M(A, I)$, thus reads

[12] In the literature, hiring costs are often paid upfront. In our setting, a part of the hiring cost c/q are paid upfront, while R_i may be paid at the start of or during the employment relationship.

$$rM(A,I) = yA + \lambda\left\{UA + J(A,I) - M(A)\right\} \tag{6}$$

where $J(A,I)$ is the value of the firm after the shock. The left-hand-side is the asset returns of a firm of value M. The right-hand-side is the sum of the flow output yA and the capital gain (or, in this case, capital loss) associated with the λ-shock. The latter consists of firm profit $J(A,I)$ and the outside option of the workforce U, less M.

We now need to specify the firm profit $J(A,I)$. When a λ-shock occurs, the firm will receive external funding with probability $1-\tau$. In this case, the firm borrows $A-I$ units. With probability τ, the firm does not get funding, and invests its I units of reserves. The firm can produce until a second λ-shock occurs, which destroys the firm. It follows that we can write $J(A,I)$ as

$$J(A,I) = \tau I\frac{y-rU}{r+\lambda} + (1-\tau)[A\frac{y-rU}{r+\lambda} - (A-I)] \tag{7}$$

The total surplus from a firm $S(A,I)$, is defined as the joint income net of the outside option of the worker, so that $S(A,I) = M(A,I) - AU$. Using equation (6), this implies

$$S(A,I) = \frac{y - rU + \lambda J(A,I)}{r+\lambda}A \tag{8}$$

Firms maximize profits. The inital cost of obtaining A machines and workers, and financial resources I, is equal to $A(1+C(U)) + \tilde{\lambda}I$. Total profits thus read

$$V(A,I) = S(A,I) - A(1+C(U)) - \tilde{\lambda}I$$

Inserting from equations (7) and (8) and manipulating gives a compact expression for the profits.

$$V(A,I) = \underbrace{\left[\frac{y-rU}{r+\lambda} - 1\right]\left(1+\widetilde{\lambda}(1-\tau)\right)A}_{Capacity} + \underbrace{\left[\frac{y-rU}{r+\lambda} - 1\right]\tau\widetilde{\lambda}I}_{Liquid\ Asset} - \underbrace{C(U)A}_{Hiring} \tag{9}$$

There are three components of the profits. The first component shows the net present profit of investing in capacity. It is the product of three factors. The first factor is the net present value of the return from investing in one machine, with the cost of labour equal to the opportunity cost rU. The second factor shows the discounted number of times each unit of capacity will be utilized in the absence of reserves, taking into account that there is a probability $1-\tau$ that the firm can reinvest, and this has to be weighted down by $\tilde{\lambda}$ since the investment happens in the future, and the firm discounts the future. The last factor is total capacity A. The second component is the net present value of investing in liquid assets. It is again the product of three terms. The first factor is again the net present value of the return from investing in one machine. The factor τ is the probability that the reserves are needed, while the factor $\tilde{\lambda}$ captures discounting. The last factor is the size of the financial reserves. The third component is the total hiring costs $C(U)A$, and it is just the product of hiring cost per worker times the number of employees.

3.4 Financial constraints

In order to invest in capacity, the firm needs finance, which is obtained in a financial market with frictions. The fixed cost F implies that there are increasing return to scale in production. Hence the firms wants to become as large as possible. However, their expansion is curbed by the availability of finance. As we anticipated in the description of the environment, we follow Holmstrom and Tirole and assume that at the initial stage the entrepreneur cannot commit to repay her entire future income to a creditor. It can only repay its pleadgeable income. While we already discussed the various theoretical motivations behind limited pledgeability, we stress that the entrepreneur cannot save her non-pledgeable income. [13]

Formally, we assume that the non-pledgeable income is proportional to the number of machines the entrepreneur controls, i.e., it is equal to xA, where x is a parameter.[14] Let $\tilde{p}$ denote the pledgeable income flow if the firm invests A units of capacity. Then

$$\tilde{p} \quad = \quad y_0 + (y - \bar{w} - x)A \tag{10}$$

where y_0 is the exogenous income flow, and $\bar{w}$ is given by (5). The NPV of the pledgeable income, $\tilde{P}$, writes[15]

$$\begin{aligned} \tilde{P} &= Y_0 + A\frac{y - \bar{w} - x}{r + \lambda} \\ &= Y_0 + A\frac{y - x - rU}{r + \lambda} - AR \end{aligned} \tag{11}$$

where $Y_0 = y_0/(r + \lambda)$, and $R = \frac{\bar{w} - rU}{r + \lambda}$ from (5). If the firm borrows $\tilde{P}$, it pays back all its pledgeable income until the machine is destroyed and the contract is terminated.[16]

The firm can use its available financial resources to invest in machines and search, or to build financial reserves. The financial constraint the firm faces can be written as $\tilde{P} \geq (\gamma/q + 1)A + \tilde{\lambda}I$. Substituting for $\tilde{P}$ gives

$$Y_0 + A\frac{y - rU - x}{r + \lambda} \geq (C(U) + 1)A + \tilde{\lambda}I \tag{12}$$

since $C(U) = c/q + R$. We denote the left-hand-side of the equation by (12) by P. Hence, the borrowing constraint reads

$$P \geq (C(U) + 1)A + \tilde{\lambda}I \tag{13}$$

where, in words, P is the pledgeable income that accrues if the firm pays the worker a wage equal to his opportunity cost rU. This can be spent on machines, direct search costs, and worker rents R (wages in excess of rU) through $C(U)$.

Note that although worker rent is paid after the worker is employed, it is total hiring cost $C(U) = \gamma/q + R$ that emerges on the right-hand-side. Hence direct search costs c/q and worker rents R tap equally much into the firm's financial resources. It follows that the financial frictions do not give the firm incentives to twist their choice of R in order to ease the financial constraint. Hence, as already anticipated, the firm will always choose to set the workers' wage so as to minimize the total hiring cost $C(U)$. We refer to this as *decoupling* between the firm's wage policy and the financial friction it faces.

Proposition 1 *Decoupling between wages and finance: financial frictions do not directly influence the firm's wage setting*

Even though the wage payment occurs later than the direct search cost, it is subtracted one to one from the pledgeable income, hence it creates the same financial burden as upfront investments in search costs.

[13] Note, however, that the assumption is easily rationalized if the non-pledgeable income is private benefits. However, the assumption is made for convenience. As long as accumulated retained earnings is likely to be less than the reinvestment needed, accumulated savings will only influence the size of the liquid asset, not whether the firm will have one or not (due to the linear structure of the model, as explained in the text).

[14] In an earlier version of the paper we showed that all the results also go through if we instead write the non-pledgeable income as a fraction of output net of the opportunity cost of workers, $\rho(y - rU)$, where ρ is a constant.

[15] We assume that $y - rU - x > 0$. This will be true in equilibrium.

[16] Note that *ex ante*, the wage-tenure profile does not matter for $\tilde{P}$, only the expeced net present value of wages until the λ-shock hits.

3.5 Financial decisions in partial equilibrium

We will now analyse the firms' financial decision. This is its choice of size A and financial reserves I in partial equilibrium, for a given value of U. To simplify notation, we suppress endogenous variables' dependence of U. The firms' financial decision solves

$$\begin{aligned} V(U) &= \max_{A,I} V(A,I) \\ \text{s.t.} \quad & I\widetilde{\lambda} + (1+C)A - P \geq 0 \\ & 0 \leq I \leq A;\ A \geq 0;\ I \geq 0 \end{aligned} \tag{14}$$

Solving for A, and assuming that the borrowing constraint binds, gives

$$\begin{aligned} A &= \frac{Y_0 - \tilde{\lambda} I}{1 + C - \frac{y - rU - x}{r+\lambda}} \\ &= k(Y_0 - \tilde{\lambda} I) \end{aligned} \tag{15}$$

We refer to $k = \frac{1}{1+C-\frac{y-rU-x}{r+\lambda}}$ as the *investment multiplier*, and it is a function of U. It shows the maximum units of capacity the firm can finance per unit of exogenous income Y_0 the entrepreneur is in possession of. It follows that

$$\frac{dI}{dA} = -\frac{1}{k\widetilde{\lambda}} \tag{16}$$

so that the borrowing constraint is just a negatively sloped line in a (I, A) space.

The firm's objective function is a linear function of A and I, and the financial constraint is also linear in A and I. Hence the firm's maximization problem generically has a corner solution. Either the firm will go for maximum capacity, or it will hold liquid assets so that it can refinance all the machines. We call the latter, the *Liquid Asset Equilibrium* (LA equilibrium, hereafter), when formally firms set $I = A$. Conversely, we call the former a *No Liquid Asset Equilibrium* (NoLA equilibrium, hereafter) and all firms set $I = 0$. By substituting the borrowing constraint into the objective function and taking derivatives, we find that the firm will choose to hold liquid assets if

$$\left[\frac{y - rU}{r + \lambda} - 1\right](1 + \widetilde{\lambda}(1-\tau)) \leq C + \left[\frac{y - rU}{r+\lambda} - 1\right]\frac{\tau}{k}. \tag{17}$$

The left-hand-side shows the gain from hiring one more worker. The right-hand-side shows the gain from having $1/k$ more units in liquid assets, including the search cost savings of not expanding capacity today.

Let D denote the difference between the right-hand-side and the left-hand-side of (17). We say that a high value of a parameter pushes the firm toward liquid assets if D is increasing in the parameter around the bliss point $D = 0$. We say that a high value of the parameter pushes the firm toward more capacity if D is decreasing in the parameter.

Lemma 1 *In partial equilibrium, for a given U, the following holds*

1. *A high probability of distress, τ, pushes the firm toward liquid assets*
2. *A high value of the pledgeability parameter x (large financial frictions) pushes the firm toward liquid assets*
3. *A high value of the search cost γ pushes the firm toward liquid assets*

An increase in τ increases the probability that the financial resources are needed, hence they are more valuable to the firm. A reduction in pledgeable income (an increase in x) reduces the multiplier k, and hence reduces the shadow cost of investing in the liquid asset. This pushes the firm towards liquid assets. An increase in the search cost γ increases C (for a given U). This has two effects. First, it reduces the multiplier. Second, it makes it more expensive to expand capacity. Botth effects increases the right-hand side of (17) and pushes the firm towards liquid assets.

4 General equilibrium

In general equilibrium, firms enter the market up to the point were the value $V(U)$ of profits is equal to the cost F of entering. Similarly, let $V^I(U)$ denote the value of a firm that holds financial reserves and sets $I = A$. In words, $V^A(U)$ and $V^I(U)$ are, respectively, the value of profits in a $NoLA$ equilibrium and in a LA equilibrium. Clearly, $V(U) = Max\left[V^A(U); V^I(U)\right]$. Hence we can define general equilibrium as follows[17]

Definition 1 *The general equilibrium of the model is a vector* (A^*, I^*, U^*, C^*) *that satisfies*

1. *Optimal search behavior by firms:* C^* *is the solution to* (3)
2. *The firms' choice of capacity* A^* *and liquid assets* I *solves (14)*
3. *Free Entry of firms,* $V(U^*) = F$

From the envelope theorem, it follows directly that $V^I(U)$ and $V^A(U)$ are strictly decreasing in U. It is also straightforward to show that $V(U) \equiv \max\{V^I(U), V^A(U)\}$ is continuous and strictly decreasing in U. Existence and uniqueness thereby follows more or less directly.

Proposition 2 *The general equilibrium exists if*

$$\frac{y - z}{r + \lambda} > F$$

Generically, the equilibrium is unique

Note that for any given U, the firms choose one of the corners $I = A$ or $I = U$, except in the non-generic case with $V^A(U) = V^I(U)$, in which case the choice of A and I are indeterminate. Furthermore, since $V(U)$ is strictly decreasing in U, the zero profit condition ensures a unique equilibrium value of U. To understand why, note that the only market parameter that influences firm profits and the financial decision is U. For a given U, a firm's financial choice is unaffected by the other firms' financial choices.

Liquid asset or firm capacity in general equilibrium

Parallel with our definition in partial equilibrium, we say that an increase in a parameter ψ (where ψ can be any parameter in the model) pushes the equilibrium towards liquid assets if, from an initial situation where firms are indifferent between holding liquidity or not ($U^A = U^I$), an increase in ψ implies that all firms hold liquid assets.

It is not trivial to see how parameters change the liquidity-size trade off, as shifts in parameters typically have several countervailing effects. In particular, studying the effects of parameter changes on the inequality (17) is a difficult route, as partial and general equilibrium effects tend to operate in opposite directions.

[17] We do not specify unemployment rates and employment in new and old firms. See the theoretical annex for details on labor stocks

Note, however, that at the point where firms are indifferent between holding liquid assets or not, $V^I = V^A = V = F$. In particular, the zero profit condition for no liquid assets without liquid assets read (from (9) and (15))

$$Y_0 k \left[\frac{y - rU^*}{r + \lambda}(1 + \tilde{\lambda}(1 - \tau)) - (1 + C(U^*)) \right] \equiv F \tag{18}$$

Let $V(I; U^*)$ denote the value of the firm that has I units of liquid assets at the equilibrium value U^*. Insert (15) into the expression for the value of a firm, (9), to get

$$V(I; U^*) = (Y_0 - \tilde{\lambda} I) k \left[\frac{y - rU^*}{r + \lambda}(1 + \tilde{\lambda}(1 - \tau)) - (1 + C(U^*)) \right] + \tau \tilde{\lambda} I (\frac{y - rU^*}{r + \lambda} - 1)$$

Taking derivatives gives

$$\frac{\partial V(I; U^*)}{\partial I} = -\tilde{\lambda} k \left[\frac{y - rU^*}{r + \lambda}(1 + \tilde{\lambda}(1 - \tau)) - (1 + C(U^*)) \right] + \tau \tilde{\lambda} (\frac{y - rU^*}{r + \lambda} - 1)$$

Inserting from (18) gives

$$\frac{\partial V(I; U^*)}{\partial I} = -\tilde{\lambda} \frac{F}{Y_0} + \tau \tilde{\lambda} (\frac{y - rU^*}{r + \lambda} - 1) \tag{19}$$

At the point of indifference, where $V^A(U^*) = V^I(U^*)$, by definition it has to be true that $\frac{\partial V(I;U^*)}{\partial I} = 0$. The next lemma follows immediately

Lemma 2 *An increase in a parameter ψ pushes the equilibrium towards liquid assets if and only if it increases the righ-hand-side of* (19).

The lemma is very convenient in order to establish how the demand for liquid assets is linked to aggregate variables. The following proposition follows almost immediately:

Proposition 3 *The following two results hold in general equilibrium*

- *Increased search costs γ pushes the equilibrium towards liquid assets, and in a frictionless market with $\gamma = 0$, firms do not invest in liquidity.*
- *An increase in y and in τ pushes the equilibrium towards liquid assets. An increase in x and in unemployment income z pushes the equilibrium away from liquid assets.*

The proposition follows more or less directly from lemma 2. A formal proof is given in the theoretical annex. The first bullet point states that there is a complementarity between financial frictions and labor market frictions. In the presence of financial frictions, a firm's desire to hold liquid assets is created by search frictions. Without search frictions, there is no search capital to protect, and the firms will not hold liquid assets. Furthermore, as higher search frictions increase the search capital, increased search frictions pushes the equilibrium towards liquid assets.

Higher output means a tighter labor market, and this increases the value of search capital. Hence, under higher productivity, firms have stronger incentives to protect the search capital by holding liquid assets.

Recall that τ reflects how frequently a firm cannot get refinancing, and hence can be considered as a measure of the quality of the financial system, with a low value of τ reflecting a high-quality financial system. The more likely it is that the financial system will fail, the stronger are the incentives to hold liquid assets. Also the parameter x reflects the quality of the financial system. A higher x increases the shadow cost of holding liquid assets. Again, a higher quality of the financial system favors size, and self-financing through liquid assets becomes less attractive.

For changes in F and Y_0, proposition 3 (or lemma 2) gives us no guidance. The direct and indirect effects (through U^*) in (19) have different signs. Hence we are unable to derive general results on whether changes in F or Y favor liquidity or not.

Comparative statics within regimes

We can easily derive various comparative static results summarized in the following proposition.

Proposition 4 *In equilibrium, the following holds*

1. *A marginal increase in the difficulty of obtaining refinancing (an increase in τ), has no effect on the LA equilibrium, while it reduces welfare U in the NLA equilibrium*
2. *Increased pledgeability (reduced x) increases the value of unemployment and the market tightness and reduces equilibrium unemployment in both types of equilibria.*
3. *An increase in firm productivity (y) increases the value of unemployment, market tightness and reduces equilibrium unemployment in both types of equilibria.*
4. *An increase in the entry cost, F, reduces the value of unemployment, market tightness and increases equilibrium unemployment in both types of equilibria.*

The proofs are straightforward and omitted.

5 Extensions

Heterogeneous firms

In our framework all firms are identical, and hence face the same trade-off regarding investment in liquid assets versus physical capacity. In order to get cross-sectional differences, we have to introduce firm heterogeneity. To this end, suppose τ is stochastic, and realized upon entry after F is sunk.[18] Let $V(U, \tilde{\tau})$ denote the value of a firm with a realization of τ equal to $\tilde{\tau}$. The zero profit condition of the firm then reads $E^{\tilde{\tau}} V(U^*, \tilde{\tau}) = F$.

Lemma 3 *Suppose that in general equilibrium, the firms prefer liquid assets if $\tilde{\tau} = 1$. Then there exists a unique τ^*, $0 < \tau^* \leq 1$, so that firms hold liquid asset if and only if $\tilde{\tau} \geq \tau^*$*

Note that $V^A(\tilde{\tau}; U^*)$ is strictly decreasing in $\tilde{\tau}$, while $V^I(\tilde{\tau}; U^*)$ is independent of $\tilde{\tau}$. Furthermore, it is always true that $V^A(0; U^*) > V^I(0; U^*)$, while, by assumption, $V^A(1; U^*) \leq V^I(1; U^*)$. Hence there exists a unique value τ^* such that $V^A(\tau^*; U^*) = V^I(\tau^*; U^*)$.

Firms with a low τ will be more leveraged than firms with high τ. Hence, the model implies that leveraged firms are larger, and fire more workers when refinancing fails than do firms with a high value of τ.

Unexpected financial crisis

We define a financial crisis as a situation in which a subset of firm creditors require that firms repay an amount $T < P$ immediately. We may think of this as credit facilities (credit lines) suddenly drying up. We assume that the crisis only lasts for an instance, so that U is not affected. Finally, we assume that the crisis is unanticipated.

For firms with liquid assets, the forced repayment shock does not create problems, as they can use their liquidity to repay T. Furthermore, since the shock lasts for an instant, the probability that a refinancing shock occurs during the crisis is zero.

In order for a firm without liquid assets to repay, it has to sell off its machines. Suppose that the scrap value of a machine is κ, $\kappa > \frac{y - rU - x}{r + \lambda}$. Hence the value of the machine is higher than the NPV of the pledgeable income flow the machine creates.[19] In order to repay the loan, the firm sells machines and lay off workers. It will have to lay off a total of H/κ workers.

[18] Note that we could just as well impose heterogeneity in terms of x or y rather than τ

[19] If this was not the case, selling off machines would make the firm insolvent

Proposition 5 *Suppose that a financial crisis hits, in the form of a repayment shock H. This has no effect on firms with liquid assets. Firms without liquid assets fire H/κ workers, and the unemployment rate increases.*

If the firm has to pay a firing tax to the replaced workers, this will increase the amount of firing the firm has to undertake. If the firing tax is t, the firm has to fire a total of $H/(\kappa - t)$ workers.

Note that as long as $\kappa < 1$, resources are lost when the firm fires the workers. For each unit of capacity it sells, the firm only pays back $\kappa < 1$ units of debt. When funds again are available, the amount the firm can borrow is smaller than before the crisis, hence the firm cannot scale up the loan to the pre-crisis level. It can be shown that each unit of capacity that the firm scraps has the same effects as reducing Y_0 with $1 - \kappa$ units in terms of borrowing potential when funds are again available (under the assumption that the laid off workers can be called back at no cost. Otherwise the set-back would be even worse). Hence the financial crisis has a scarring effect on employment in existing firms.

Wage bargaining after the shock

In the baseline model, we assumed that if production continued after a λ-shock, the firm had all the bargaining power and workers were receiving their outside option U. We now relax this assumption. We assume that the workers at that stage bargain over the wage, and receive a share α of the surplus. The surplus per worker after the shock is $\frac{y-rU}{r+\lambda}$, hence the worker who is retained gets a surplus $\alpha\frac{y-rU}{r+\lambda}$. Note that the reinvestment cost is not a part of the surplus the agents bargain over. We assume that the worker's bargaining power is not too high so that firms will invest after the shock if funding is available.

We assume that when a job is advertised, it is informed whether the firm has financial resources so that the job can continue after a shock. If this is the case, we say that the job is funded. In other words, the worker can observe the financial assets I, and if $I < A$, which jobs the funds are attached to (this is not important, as in equilibrium either all or none of the jobs are funded). Hence workers, when evaluating the attractiveness of the job, take into account whether the job is funded or not. We shall now indicate with R_2^i ($i \in \{0, 1\}$, $i = 1$ if the vacancy is funded, 0 if it is not), the net present value to the worker of the rents obtained through bargaining after a negative shock. The subscript 2 refers to the second period in the life of the firm, after the first λ shock hits. R_2^i ($i \in \{0, 1\}$, $i = 1$ if funded) is given by

$$R_2^i = \tilde{\lambda}\alpha[\frac{y - rU}{r + \lambda}((1 - \tau) + \tau I[i = 1])]$$

where $I[i = 1]$ is an indicator function, equal to 1 if the job is funded and 0 if it is not.

The firm's trade-off between rents and search costs is not altered by renegotiation *ex post*. In particular, the firm still minimizes $C(U)$ defined by (3) with solution (4). Let R be total rent the worker receives, and R_1 the rent the worker receives before the shock hits (which is equal to $\frac{\bar{w}-rU}{r+\lambda}$ with constant wages). Note that it is only R_1 that is paid out before the shock hits. The worker only cares about the total rents $R = R_1 + R_2^i$ that she gets, not the time profile of the rent. As a result, the worker captures some of the rent after the shock comes at no cost to the firm, as the firm can reduce the rent given to the worker before the shock occurs dollar for dollar. Furthermore, since R_2^i is exogenous to the firm for a given i, attracting workers by paying higher wages or by paying for vacancies, at the margin, taps equally much into the firm's financial reserves. Hence *ex post* bargaining does not change the rents/search cost trade-off the firm faces. This implies that the decoupling between wages and financial frictions outlined in proposition 1 is still valid.

Nevertheless, giving bargaining power to the workers after the shock reduces the wage the firm has to pay before the shock, and eases the financial constraint of the firm. Let $\tilde{C}^i(U) = C(U) - R_2^i$ denote the part of the total hiring cost that is paid out before the shock hits. It follows that (12) reads

$$
\begin{aligned}
Y_0 + A\frac{y - rU - x}{r+\lambda} &\geq (\tilde{C}^0 + 1)A - \tilde{\lambda}(1 - \tau\alpha\frac{y - rU}{r+\lambda})I \\
&= (\tilde{C}^0 + 1)A - \hat{\lambda}I
\end{aligned}
$$

where $\hat{\lambda} = \tilde{\lambda}(1 - \tau\alpha\frac{y-rU}{r+\lambda})$, which clearly is less than $\tilde{\lambda}$. It follows that the multiplier, $\hat{k}$, is given by (analogous to 15)

$$
\hat{k} = \frac{1}{1 + \tilde{C}^0 - \frac{y-rU-x}{r+\lambda}}
$$

Comparing the multiplier $\hat{k}$ with the value of k in the case of no renegotiation of equation (15), it follows that $\hat{k} > k$.

The *ex ante* asset value function of the firm profit is unchanged. Note that the reduction in *ex post* profits after the λ-shock is realized exactly offsets the reduced cost of attracting the worker before the shock, $C(U) - \tilde{C}(U)$. We can now rewrite (17) as

$$
\left[\frac{y - rU}{r+\lambda} - 1\right](1 + \widetilde{\lambda}(1-\tau)) \leq C + (\left[\frac{y - rU}{r+\lambda} - 1\right]\frac{\tilde{\lambda}}{\hat{\lambda}}\frac{\tau}{\hat{k}}. \tag{20}
$$

The impact of wage bargaining on the size-liquid asset trade-off is not clear, as $\hat{\lambda} < \tilde{\lambda}$ while $\hat{k} > k$. However, for τ sufficiently large, *ex post* wage bargaining makes liquid assets more attractive (as τ goes to 1, $\hat{k}$ goes to k). Hence there exists a $\hat{\tau} \geq 0$ such that the following Lemma follows.

Lemma 4 *With ex post renogatiation and value of $\tau > \hat{\tau}$, ex post, wage bargaining makes liquid assets more attractive.*

Note also that the structure of equation (17) and equation (20) is the same, hence Lemma 2 still holds.

Let us then turn to general equilibrium. Since the asset values are unaffected, it follows that equation (19) can be rewritten as

$$
\frac{\partial V(I; U^*)}{\partial I} = -\hat{\lambda}\frac{F}{Y_0} + \tau\hat{\lambda}(\frac{y - rU^*}{r+\lambda} - 1) \tag{21}
$$

In the theoretical annex we show that proposition 3 still holds. Hence, although wage bargaining *ex post* eases the financial constraint, the responses of changes in parameters on the demand for liquid assets are unchanged.

6 Discussion and implications

In this paper we integrate limited pledgeability with labor market imperfections. We construct an archetype model for analysing the interplay between labor and financial imperfections. There are at least four main lessons that can be learned from our theory.

First, we uncover a key complementarity between firms holding of liquid assets and labor market imperfections. In our model the corporate sector holds liquidity as a way to protect its search capital. The latter is defined as the total hiring cost created by labor market imperfections. The model predicts also that firms do not hold liquid assets when labor market frictions disappear. While we are aware that the precautionary motives for firms holding cash and liquid assets are many, the complementarity between liquid assets and labor market imperfections is novel and should be investigated in future empirical work.[20] If we take literally the structure of our model, the larger are the labor market frictions, the larger should be the amount of cash held within the firms. We thus expect that firms operating within very tight labor markets will be more proned to hold liquid assets. Future empirical research may assert this relationship in detail.

Second, our theory predicts that those firms that hold more liquid assets should be more protected to adverse shock hitting their lender. The recent empirical evidence, as well as the facts and regressions reported in section 2, suggest that more leveraged firms dismissed more workers during the Great Recession. In our baseline model, the firm borrows $\tilde{P}$ given by (11). The value of the firm is the entrepreneurs investment $F + Y_0$. The leverage ratio can be defined as loans divided by total assets, and is given by

$$LE = \frac{\tilde{P}}{\tilde{P} + K + Y_0} \tag{22}$$

where $\tilde{P} + K + Y_0$ is total assets. Since $\tilde{P}$ is increasing in A, the leverage ratio will tend to be higher for firms that do not hold liquid assets than for firms that do. Furthermore, firms with $\tau < \tau^*$ should be less leveraged than firms with $\tau > \tau^*$. Our model predicts that there is more firing in the no-liquid assets equilibrium during the crisis, and firms with no liquid assets fire more than firms with cash. This is consistent with our motivating facts.

Third, our results on wage bargaining indicate that empowerment of workers may have consequences for the financial decisions of firms. First, our model indicates that empowerment of workers may ease the financial constraints of the firm, as it will act as a commitment device, and allowing the firm to borrow from their workers' future earnings (earned after the shock). Furthermore, provided that a financial shock is sufficiently likely, it also changes the trade-off between liquid assets and size in the direction of liquid assets.

Fourth, our theory predicts that firms embedded into better functioning financial sectors should be, on average, more leveraged and less inclined to hold cash. In addition, the theory predicts that a more financially integrated system should dismiss more labor under adverse financial conditions. We believe that the dynamics of the US labor market in the early 2007, when compared to the European experience in the aftermath of the financial shock, is quite revealing in this respect. The US corporate sector is arguably more financially integrated than the European one (Rajan Zingales, 1998). When the financial shock hit in 2007, the US unemployment rose quickly from 5 to 9 percent, while European unemployment rose only modestly. It is certainly true that labor market institutions in Europe reduced labor shedding, but the dramatic rise in US unemployment is likely to have been the counterpart of its finance orientation. The evidence reported in Boeri Garibaldi and Moen (2013) is coherent with this interpretation.

Admittedly, there is a caveat to the last argument. Although recent micro evidence assembled for the US (Chodorow-Reich, 2014) clearly suggests that the health conditions of the lender had a significant impact on the firm propensity to reduce employment during the financial crisis, this evidence is silent on the role of liquid assets. Indeed, the large firms in the US corporate sector became a net lender at the beginning of the 2000s. Armenter Hnatkovska (2012) show that in a sample of 6000 listed firms in Compustat, 44 percent had positive net financial assets in 2007, at the outset of the financial crisis.[21] How is it possible to reconcile the importance of cash holdings in the US with the large employment losses observed in 2007 and linked to the lender health by the Chodorow-Reich (2014) findings? We argue that this does not count against our model, for several

[20] Opler et al. (1999) argue that in general there are precautionary and transaction motives for the firms holding cash. First, the firm saves transaction costs to raise funds and does not have to liquidate assets to make payments. Second, the firm can use the liquid asset to finance its day to day activities if other sources of funding are not available. Armenter and Hnatkovska (2012) argue that firms accumulate cash holdings in order to avoid being financially constrained in the future. In their paper firms operate within a perfect labor market and must resort to costly equity every now and then. It turns out that the value function is strictly concave even if their utility is linear.

[21] Kararbounis and Meinman, 2012 link changes increase in corporate savings to changes in labor income shares

reasons. First, our model is best suited to describe small, privately held firms, while the liquid assets observed were held mainly by large listed (often multinational) firms. Huasheng et al. (2012) clearly show that private firms hold less than half as much cash as public firms do. In addition, they also report evidence that the private firms adjust more slowly to their desired liquid assets. Lastly, the listed firms in Compustat held liquid funds in 2007 according to the accounting classification, but such liquid funds were not necessarily so liquid. They may indeed have been very illiquid, particularly when the crisis hit.

7 Final remarks

Interaction between labor and finance is a growing field, as shown by the literature briefly reviewed in this paper. We contribute to this field by integrating the traditional DMP model with the limited pledgeabilty friction developed by Holmostrom and Tirole. The result is a tractable micro-founded model of labor-finance interactions that generates a demand for liquid assets inside the firm. The model yields a number of testable implications. The most relevant in the context of the Great Recession is that highly leveraged firms should experience larger employment losses during a financial crisis. Consistently with previous studies, based on micro data on employment adjustment and balance sheets, we find that highly leveraged firms and sectors are indeed characterized by higher job destruction rates during financial recessions.

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Theoretical annex

Derivation of optimal search equations

The constraint implicitly defines an indifference curve $\theta = \theta(R, U)$ where U is the given value of unemployment. Further

$$\frac{d\theta}{dR} = -\frac{\theta q(\theta)}{q(1-\beta)R}$$

where β is the absolute value of the elasticity of $q(\theta)$, independent of θ under a Cobb-Douglas specification of the matching function. Total search costs define implicitly an isocost and the equilibrium is going to be a tangency condition between the isocost C and the indifference curve U.

Formally, the first order condition for a minimum- once we use the indifference curve - is thus

$$\frac{\gamma q'(\theta)}{q^2}\frac{\theta q(\theta)}{q(1-\beta)R} = 1$$

or

$$R = \frac{\gamma}{q}\frac{\beta}{1-\beta}$$

Total hiring cost is thus

$$C = \frac{\gamma}{q}\frac{1}{1-\beta}$$

Over and beyond the rent, the firm pays the worker a flow value rU per period employed. Finally, θ is given by

$$\theta q(\theta) = \frac{rU - z}{R} = (rU - z)\frac{1-\beta}{\beta}\frac{q}{\gamma}$$

hence

$$\theta(U) = \frac{rU - z}{\gamma}\frac{1-\beta}{\beta} \tag{23}$$

Worker flows and stocks

To complete the specification of the economy we have to account for the aggregate labor flows. In the economy there is a measure 1 of workers who can be employed in new firms or firms that already experienced the first λ shock. We label respectively n_1 and n_2 the share of workers employed in the two types of firms. In the war chest equilibrium, conditional on a λ shock firms do not fire any worker and continue with their cash holdings. Let ω be an indicator function that takes value 1 if the economy is in a no-cash equilibrium. The general balance flow conditions read

$$\begin{aligned} \theta q(\theta)u &= \omega\lambda n_2 + (1-\omega)(\lambda\tau n_1 + \lambda)n_2 \\ \omega\lambda n_1 + (1-\omega)(\lambda(1-\tau))n_1 &= \lambda n_2 \\ u + n_1 + n_2 &= 1 \end{aligned}$$

The first equation is simply the outflows from unemployment and inflows into unemployment, where the latter involves also the share of workers in type 1 firms that do not find refinancing in the $NoLA$ equilibrium. The second condition is the flow into n_2 from type 1 firms and outflows out of n_2. Again, in the $NoLA$ equilibrium only the surviving employed enter the type 2 state. The last condition is the aggregate labor market condition. Solving for the stock yields

$$
\begin{aligned}
u &= \omega \frac{\lambda}{\lambda + 2\theta q(\theta)} + (1-\omega)\frac{\lambda}{\lambda + (1+(1-\tau))\theta q(\theta)} \\
n_1 &= \omega \frac{\theta q(\theta)}{\lambda + 2\theta q(\theta)} + (1-\omega)\frac{\theta q(\theta)}{\lambda + (1+(1-\tau))\theta q(\theta)} \\
n_2 &= \omega \frac{\theta q(\theta)}{\lambda + 2\theta q(\theta)} + (1-\omega)\frac{\theta q(\theta)(1-\tau}{\lambda + (1+(1-\tau))\theta q(\theta)}
\end{aligned} \tag{24}
$$

Proof of proposition 3

Proof: It is straightforward to show that U^* is decreasing in γ. It follows that an increase in γ increases the right-hand side of (19), and hence makes liquidity more favorable. Furthermore, in the limit, as $\gamma \to 0$, one can easily show that $C \to 0$, $\theta \to 0$ and $R \to 0$. The labor market is competitive with a wage $w = rU < y$.[22] Equation (17) then reads

$$(1 + \widetilde{\lambda}(1-\tau)) \leq \frac{\tau}{k}$$

where $k = \frac{1}{1-\frac{y-w-x}{r+\lambda}} > 1$. As the left-hand-side is strictly greater than one, while the right-hand-side is strictly less than one, the result follows.

An increase in y increases $y - rU$. Suppose not. Then it follows from (9) that profits per worker fall strictly, and from (15) that the financial constraint tightens. Hence profits fall, a contradiction. It follows that $y - rU$ decreases, and hence that holding liquid assets is more likely. An increase in τ reduces V^A while it does not influence V^I. An increase in τ therefore makes cash more likely. Finally, an increase in x increases U^*, and hence reduces the left-hand-side of (19).

Proof related to general equilibrium with bargaining

Taking derivatives of (21) with respect to U^* gives

$$
\begin{aligned}
\frac{\partial^2 V(I;U^*)}{\partial I \partial U*} &= \frac{\partial \hat{\lambda}}{\partial U^*}[\frac{F}{Y_0} + \tau(\frac{y - rU^*}{r+\lambda} - 1) + \hat{\lambda}\frac{\partial}{\partial U^*}\frac{F}{Y_0} + \tau(\frac{y - rU^*}{r+\lambda} - 1) \\
&= \hat{\lambda}\frac{\partial}{\partial U^*}\left[\frac{F}{Y_0} + \tau(\frac{y - rU^*}{r+\lambda} - 1)\right]
\end{aligned} \tag{25}
$$

Since $\frac{\partial V(I;U^*)}{\partial I} = 0$ initially. Hence changes in the parameters γ, y, τ and x shifts the rhs of (19) and (25) in the same direction, hence proposition 3 still holds.

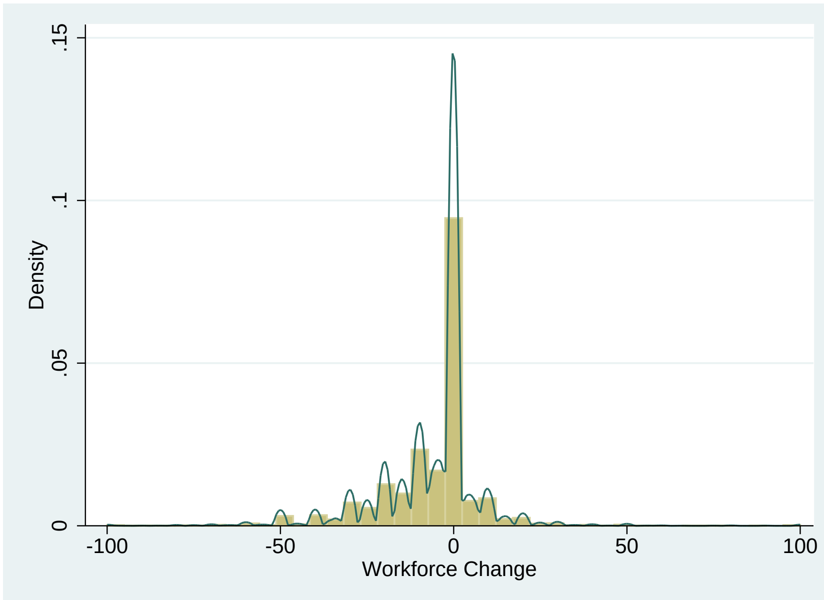
Statistical annex

Figure 2 plots the distribution of employment changes across firms in the EFIGE survey, using also a Kernel density estimator (blue line) to characterise the distribution. As data refer to a global recession year, most firms appear to be downsizing: the median is 0, the mean is -6. In addition to the mode at 0, there are also some spikes at -10, -20 and -30. This may indicate that respondents answered doing some rounding. Some of our estimates below take into account of such heaping problems.

Table 2 provides some descriptive statistics on the measures of leverage which are used in the empirical analysis in 2007, the year before the beginning of the Great Recession. In particular, the

[22] Even in the limit, firms don't grow infinitely due to the borrowing constraint, hence wages must be below productivity in order for the firms to capitalize on K.

Figure 2: Firm-level net employment change, Distribution of firms



Gearing ratio is the debt to equity ratio measuring the extent to which the firm is using creditor's vs. owner's funds. As shown by table 2, there is significant cross-country and within country (across sectors) variation in these measures. At the same time, there are large differences in the average size of firms across countries, which confirms that data are not cross-country comparable.

Table 3 reports OLS and IV regressions limited to either firms downsizing or expanding employment levels. In the 2SLS estimates the instrumented gearing ratio is significant only in the case downsizing firms.

The effects of leverage survive when we put on the left-hand-side a categorical variable (0 for downsizing, 1 for firms keeping the same employment level, 2 for those upsizing) in order to cope with the heaping problems mentioned above.

Table 2: Measures of Leverage, Descriptive Statistics

Country	Number of Firms	Revenues growth 2008-2009		Size of Firms (Employees 2007)	
		Average	Standard Deviation	Average	Standard Deviation
AUT	443	63.5%	0.740	100	33
FRA	2,973	-8.3%	0.010	50	8
GER	2,935	-5.2%	0.008	96	11
HUN	488	-12.4%	0.015	68	9
ITA	3,021	-18.6%	0.005	40	2
SPA	2,832	-16.8%	0.015	45	3
UK	2,067	0.1%	0.032	20	773

Variable	Average	Min	Max	Standard Deviation
Gearing Ratio (2007)	1.20	0.00	997.53	175.46
Δe	-6.18	-100	100	15.16
$\Delta \bar{y}$	-0.09	-0.30	5.64	0.39
Size of Firms (2007)	116.65	0.00	365,630	3,595.00
Third Party Collateral	0.04	0	1	0.21

Table 3: Regression on downsizing and expandind firms

	Sample: Only Firms Downsizing	
	(3)	(4)
VARIABLES	Δe(%) Employment Growth	Δe(%) Employment Growth
Method	OLS	IV
	Second stage	
Gearing [a]	-0.003**	-0.034*
	(0.001)	(0.017)
$\Delta \bar{y}$ [b]	0.547	95.87
	(1.243)	(132.8)
	First stage	
		Gearing
Third party collateral		88.366***
		(21.310)
Observations	4151	1195

	Sample: Only Firms Upsizing	
	(5)	(6)
VARIABLES	Δe(%) Employment Growth	Δe(%) Employment Growth
Method	OLS	IV
	Second stage	
Gearing [a]	-0.0041*	0.0354
	(0.0023)	(0.171)
$\Delta \bar{y}$ [b]	-0.0915	33.53
	(3.048)	(679.9)
	First stage	
Third party collateral		31.11***
Observations	1060	307

All regressions include a constant and dummies for , Country, Sector, Size and Country*Sector
[a] Gearing Ratio is the debt to equity ratio
[b] Change in output at the sectoral level
Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: All Firms

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$
Method	OLS	OLS	IV	IV	IV	IV
Second stage						
$\Delta \bar{y}$	1.107	1.049	-57.31	98.56	-95.87	-33.53
	(0.910)	(0.901)	(133.3)	(169.1)	(132.8)	(679.9)
Gearing	-0.004***		-0.029**		-0.34*	0.0354
	(0.001)		(0.012)		(0.017)	(0.171)
Solvency		0.04***		0.603***		
		(0.006)		(0.213)		
Constant	-8.123***	-10.73***	-13.09	-13.19	-24.75	0.976
	(2.594)	(2.630)	(17.11)	(20.69)	(16.62)	(106.2)
ountry	YES	YES	YES	YES	YES	YES
Sector	YES	YES	YES	YES	YES	YES
Country*Sector	YES	YES	YES	YES	YES	YES
Size	YES	YES	YES	YES	YES	YES
First stage						
			Gearing	Solvency	Gearing	Gearing
Third party collateral			108.24***	-6.846***	88.366***	31.11***
			(16.476)	(1.686)	(21.310)	(68.121)
Observations	8596	9649	2358	2900	1195	307

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: All firms (Δe categorical)

	(1)	(2)	(3)
VARIABLES	$\Delta e(\%)$	$\Delta e(\%)$	$\Delta e(\%)$
$\Delta \bar{y}$	-0.0157	-0.0165	-0.0201
	(0.0420)	(0.0411)	(0.0426)
Gearing	-0.000160***		
	(3.95e-05)		
Solvency		0.00104***	
		(0.000293)	
Constant	0.589***	0.522***	0.541***
	(0.120)	(0.120)	(0.119)
Country	YES	YES	YES
Sector	YES	YES	YES
Country*Sector	YES	YES	YES
Size	YES	YES	YES
Observations	8,693	9,757	8,161
R-squared	0.078	0.076	0.072

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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