Labor and Capital Dynamics under Financing Frictions

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Abstract

This paper integrates a model of rich firm-level dynamics, including factor adjustment frictions and wage setting, with a theory of costly debt and equity financing. The theory can confront a variety of empirical moments relating to the cross sections of debt, employment growth, and capital investment. The model is estimated by method of simulated moments. The estimation makes use of a new quarterly panel dataset that links a firm's investment and financing decisions to its employment and wages. Using the estimated parameters, we assess the model's ability to replicate recent reduced-form evidence on the effects of financing frictions on capital and labor demand.

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1. Introduction

It is safe to say that several decades of economic research have taught us that financial frictions are important for firm-level investment. From the early descriptive work of Fazzari, Hubbard, and Petersen (1988) to the natural experiments and quantitative exercises in, for example, Chava and Roberts (2008) and Hennessy and Whited (2007), we have learned that financial frictions causally impact investment, and that these effects can be large. What is less well understood is the impact of financing frictions on factors of production besides capital. Striking evidence of this impact is documented in Duygan-Bump, Levkov, and Montoriol-Garriga (2015) and Chodorow-Reich (2014), both of which examine the enormous uptick in job loss immediately following the failure of Lehman Brothers in 2008. In addition, several other studies, such as Cantor (1990), Sharpe (1994), and Bakke and Whited (2012), have shown that financing frictions affect labor demand outside of extreme credit market failures. Interestingly, all of these studies are silent about the interaction between financial frictions and wage setting.

We enter this picture with new data and a new model. On data front, we construct a quarterly, firm-level panel dataset by merging two sources of data. The first is Compustat, which includes quarterly investment and balance-sheet data. However, Compustat contains only annual observations on employment and virtually no data on wages. We fill in these missing pieces using the Bureau of Labor Statistics' Longitudinal Database of Establishments (LDE), which provides quarterly observations on establishments' total wage bill and employment. To our knowledge, studies of financing frictions have lacked a dataset of this scope. The quarterly frequency enables us to capture the kind of precipitous changes in factor demand witnessed around the 2008–2009 financial crisis. In addition, the information on the wage bill is especially important and novel. As we will see, the firm's demand for external finance depends, in part, on the size of the wage bill relative to its own internal funds. This feature of the model makes it critical to observe the level and dynamics of the wage bill, and to tie these observations directly to the firm's cash flow and balance sheet.

With these data, we first characterize and describe firms' optimal factor demand policies. Some of our findings reassuringly confirm established facts in the labor economics literature. For example, we find that labor earnings covary positively with sales. However, our two most interesting descriptive findings are new. First, labor earnings per worker covary negatively with leverage, both in the cross section and within firms. Moreover, the within-firm variation is stronger in firms without bond ratings, suggesting a link between this correlation and financial frictions. Second, employment does not appear to covary with leverage significantly for any sample. Although we do find a negative correlation when we examine this correlation at an annual frequency, the statistical significance is marginal.

Next we seek to understand the primitive economic forces behind these observed corporate policies, as well as to understand more broadly how financial frictions interact with both employment outcomes and wages. In particular, we ask what constellation of real and financial frictions are necessary for us to have observed these facts in the data. To this end, we develop an integrated theoretical treatment of external finance and realistic labor and capital demand. Our model combines financial frictions into a a model of rich factor demand dynamics, which are generated by careful treatments of both capital and labor adjustment, in addition to wage bargaining.

In this setting, we find that the existence of financial frictions are a necessary, but by no means sufficient condition for generating the firm policies observed in the data. With financial frictions in place, wage bargaining engenders an endogenous negative relation between earnings per worker and leverage. This relation bears an intuitive connection to the debt overhang problem in Hennessy (2004). High leverage limits the states of the world in which firms have sufficiently liquidity to pay workers, so average wages are lower. Next, relatively modest labor adjustment costs inhibit the natural negative relation between employment growth and leverage.

A better understanding of these results requires a more complete description of the model.

Firms in our dynamic model make investment, hiring, and financing choices. In so doing, they confront factor adjustment frictions. We assume in particular that the firm is subject to per-capita costs of hiring, following a literature dating back to Oi (1962).[1] With respect to capital demand, we assume that if a firm chooses to disinvest, it cannot recover the full purchase price. In other words, investment is only partially reversible, consistent with evidence in Ramey and Shapiro (2001), Cooper and Haltiwanger (2006), and Bloom (2009).

The firm can finance its factor demands in many ways. First, the firm can write a standard debt contract, which takes the form in Townsend (1979) and Bernanke and Gertler (1989). The firm makes a non-contingent payment to the lender if its productivity exceeds a certain threshold. Otherwise, the firm defaults, and the lender is awarded a share of the firm's assets, where this share can be interpreted as the collateralizable fraction of assets. The contractual loan rate is the price that equates the risk-free return to the expected return from defaultable debt, thereby leaving the lender indifferent. Alternatively, the firm can raise external funds by issuing equity, which incurs underwriting costs. In the model, these costs give rise to equity issuances that are as infrequent as those observed in the data. Indeed, in our setting, issuing equity is the financing option of last resort. Lastly, the firm can attempt to circumvent these financing constraints by accumulating liquid assets and deploying them in financing factor demands. This feature is important, given the point in Midrigan and Xu (2014) that firms can neutralize financing constraints by accumulating savings during good times.

A novel aspect of the model, in the context of the literature on financing constraints, is the treatment of wage setting. A bargaining problem arises in our model because the costs of employment adjustment imply the existence of rents to ongoing firm-worker matches. We assume these rents are divided according to the bargaining protocol developed in Stole and Zwiebel (1996), and also used by Elsby and Michaels (2013). We believe we are the first to

[1] More recent estimates of hiring and firing costs, spanning a variety of methods, can be found in Anderson (1993), Barron, Berger, and Black (1997), Cooper, Haltiwanger, and Willis (2007), and Silva and Toledo (2009).

show how this bargaining game can be extended to a model where payroll can be financed using defaultable debt.

Financing decisions and the wage bargain interact in interesting ways. Once the wage bargain is concluded, productivity is realized, and production ensues. At the start of the next period, accounts are settled; and if default occurs, it happens at this point. An intuitive result that emerges is that the wage rate is declining in the firm's liabilities. The reason is that a highly levered firm is more likely to default, in which case the firm's output is seized by its lenders. Accordingly, the expected return to the firm from employing a worker is declining in leverage, resulting in a lower wage bargain. Enabling the firm to bargain a lower wage after adverse productivity realizations represents a potentially important margin of adjustment in models with financial frictions, because it is the firm's desired *payroll* that influences its demand for external funds.

This integration of external finance with both labor and capital demand is unique in the literature. Most of the models of financial frictions surveyed in Strebulaev and Whited (2012) abstract from capital adjustment costs, for instance. Further, all assume that workers are hired in a spot market and remunerated concurrently with production. Under these conditions, a firm can always implement the static optimum, so financial constraints have no independent effect on employment (Ejarque 2002). By the same token, prominent models of factor adjustment, such as Bloom (2009) and Cooper et al. (2007), assume that external financing is frictionless, that is, external financing can be obtained at the same rate that the firm discounts its cash flows.

We estimate the model's parameters using the method of simulated moments in which the structural parameters are chosen to best fit a wide-ranging set of facts on factor accumulation and external funds, such as moments from the distributions of debt holdings, employment growth, and capital investment. The identifying information embodied in these moments is often intuitive. For instance, the choice of the variance of idiosyncratic productivity balances evidence on the size of factor adjustments with the incidence of corporate borrowing: a higher variance can account for the dispersion in factor adjustments but also encourages substantial precautionary saving, limiting the incidence of issuing risky (defaultable) debt. In this sense, the cross sections of factor demands help inform the choice of parameters that have significant implications for the prevalence and operation of external financing.

Using the estimated parameters, we then document the model's implications for factor dynamics in two ways. First, we examine how the sensitivity of employment and wages to leverage change with various model parameters. This type of out-of-sample test serves as a valuable check on our understanding of the aforementioned reduced-form results.

Second, we conduct acounterfactual experiment in the spirit of recent microeconometric analyses. We mimic the effect of being matched with an "unhealthy" lender, as in Chodorow-Reich (2014). In our model, we implement this experiment by matching a sample of firms in our simulations exogenously with a lender that bears a relatively high cost of funds. We then compare the outcomes of these treated firms with those firms that continue to have access to lower-cost lenders. We find marked effects of this shock on labor demand, and as in the case of our first experiment, parameters that govern both the real and financial sides of the model have pronounced effects on this response. Here, we find that higher labor bargaining power leads to a greater response of labor demand to the interest rate shock. The intuition is that although the wage becomes more flexible, the workers also grab more of the bargaining surplus. The firm can mitigate this by increasing leverage and "threatening default." As a consequence, though, firms are more highly levered when the shock hits, which amplifies its effect.

Our interest in an integrated treatment of costly factor adjustment and external finance is perhaps most closely related in recent literature to DeAngelo, DeAngelo, and Whited (2011) and Gilchrist, Sim, and Zakrajsek (2013). We differ from this work principally in our treatment of labor demand. Gilchrist et al. (2013) abstract from frictions in employment adjustment and enable the firm to compensate workers concurrently with production. As a result, the choice of employment collapses to a simple static problem. Similarly, although

DeAngelo et al. (2011) model rich capital adjustment costs, their technological assumptions embody a static, frictionless labor choice.

Two additional papers are important antecedents to our study. Monacelli, Quadrini, and Trigari (2011) consider a related wage bargaining problem in the presence of financing constraints. We generalize their setting in several ways. First, we include both capital and labor in our model, and we assume decreasing returns, which ensures a well-defined notion of firm size that is essential for our empirical analysis. Second, separations (firing) are endogenous in our setting, whereas they occur at an exogenous rate in Monacelli et al. (2011). Quadrini and Sun (2014) examine the effects of costly external finance on worker bargaining in an industry equilibrium model. However, in contrast to our own work, they do not model capital and therefore cannot explore the interactions between financing and different factor demands. Further, although they estimate some of their model parameters, they do not have the rich employment and wage data that we use.

The rest of the paper proceeds as follows. Section 2 describes our new quarterly data set on employment, wages, and firm balance sheet and income statement information. Section 3 presents and analyzes the model. Section 4 describes our estimation procedure and presents our results. Section 5 presents our counterfactual experiments, and Section 6 concludes. The Appendices contain details about data construction and the model.

2. Data

2.1. Data construction

Our quantitative analysis of the theory is made possible by a new firm-level dataset that we have assembled. The dataset connects observations on employment and labor earnings at the establishment level with information on investment and the balance sheet at the firm level. This section describes the construction of the dataset.

The dataset is assembled by merging three data sources. Information on standard balance sheet and income statement items, such as sales, operating income, capital investment, the stock of debt, and cash holdings, is from the nonfinancial and unregulated firms in the 2013 quarterly Compustat industrial files. Because equity issuance data in Compustat contains a great deal of employee stock option exercise, we obtain equity issuance data from the SDC Platinum Global New Issuance database. We include Secondary Equity Offerings (SEOs) by U.S. nonfinancial firms, and we exclude rights issues and unit issues, as well as observations with missing values for total proceeds or a launch date. We obtain data on these two variables, as well as the total underwriting fee, the CUSIP number, and Ticker symbol of the ultimate parent of the issuer.

Compustat also lacks high-frequency data on employment and wages; indeed, data on labor earnings are largely missing.[2] To deal with this issue we turn to the BLS' Longitudinal Database of Establishments (LDE), which is a panel dataset that is assembled from the Quarterly Census of Employment and Wages. The latter is derived from employers' Unemployment Insurance (UI) files, which provide a monthly record of the level of employment and the total wage bill at each UI-covered employer in the United States. The LDE is available from 1992 to the present.

Although monthly data are available, we aggregate observations over the quarter from the LDE to conform with the structure of the Compustat quarterly files.

The most significant challenge in merging the datasets is that Compustat is a panel of *firms*, whereas the LDE is a panel of *establishments*. The question, then, is how to identify a parent firm's establishments in the LDE. This matching can be done using *solely* the identifying information available in Compustat and LDE only in special circumstances. Each establishment in the LDE reports an Employer Identification Number (EIN), which

[2]We show below that just 5% of nonfinancial firms consistently disclosure labor earnings in Compustat (item XLR) during our sample period. An alternative to item XLR is selling, general, and administrative (SGA) expenses. However, SGA omits the "cost of goods sold," which includes the earnings of non-managerial employees. Further, SGA includes many items, such as materials, that we wish to isolate from labor earnings.

is assigned to it by the Internal Revenue Service. If the individual establishment reports the same EIN that the parent firm uses in its public disclosures, then one can match it to its parent firm's information in Compustat. However, it is common for parents to operate under different EINs in different states (Haltiwanger, Jarmin, and Miranda 2013). Hence, there can be many EINs associated with a parent that operates across multiple states. This problem means that merging on EINs are alone is inadequate.

These problems force us to turn to an auxiliary data source that provides a list of establishments associated with each parent firm. Infogroup is a private data collection company that maintains a database known as ReferenceUSA, which records the names and addresses of individual establishments in the U.S.. For each establishment, ReferenceUSA records the parent firm and, if applicable, the subsidiary of the parent under which the establishment operates. Infogroup places millions of phone calls to U.S. establishments to compile these data.[3]

Using ReferenceUSA as a bridge, the merge between Compustat and LDE can be done in two steps. First, we merge a list of establishments from ReferenceUSA to their corresponding entries in the LDE, using a character-matching algorithm.[4] The second step aggregates employment and wages across all (matched) establishments within each parent firm. These aggregates are then merged with Compustat. The latter merge is straightforward because Infogroup includes the parent name, as recorded in Compustat, alongside each of the establishments in its list.

Because the ReferenceUSA data are prohibitively costly, we do not carry out this merge for the universe of Compustat firms. Rather, our dataset consists of a random sample of 588 firms listed in Compustat and covers the years 2006 through 2012. The sample is, to some extent, tilted toward smaller firms, as we exclude large multinationals from our analysis.

[3]Infogroup reports that its databases "power the directory services of the top traffic-generating Internet sites including Yahoo!, InfoSpace, and Microsoft."

[4]We thank (without implicating, of course) Dominic Smith (see Bayard, Byrne, and Smith 2013) for providing matching code on which we base our analysis. Please see the Appendix for further details regarding this merging process and related issues.

First, they are less likely to inform us on financial constraints, the topic of our study. Second, because the BLS data pertain to the United States, we want to match domestic employment dynamics to (by and large) domestic operations in Compustat. Please see Appendix A for further details regarding the merging process, sample construction, and detailed variable definitions.

2.2. Characteristics of the sample

This section describes our data. Our goal is twofold. First, a comprehensive dataset on employment, labor earnings, investment, and finance is new to the literature, so we first simply set out to examine basic reduced-form correlations. Second, this investigation gives us a set of stylized facts upon which our model can shed light.

First, we report a few summary statistics on our sample. To begin, we emphasize the differences between our sample and the rather select sub-sample of Compustat firms that disclose total labor earnings. Ballester, Sinha, and Livnat (2002) report that few firms in Compustat disclose total labor earnings, and this sample consists disproportionately of large firms in more regulated industries. Table 1 updates their results, using the period 2006-2012. A disclosing firm is defined here as one which reports positive labor earnings data in each year of this period. There are 468 disclosing firms, out of a universe of 9309 nonfinancial firms. The table shows that both average employment, revenue and assets among disclosing firms are about 3 times that of non-disclosing companies. In addition, 27% of disclosing firms are classified in the relatively highly regulated transportation and utilities sector, compared to 10% of non-disclosing firms.

Table 1 also contrasts the Compustat universe with our merged sample. Firms in our panel are quite similar to the non-disclosing universe, in terms of sales and employment. With respect to the industry structure, manufacturers make up a larger share in our sample than in Compustat, and natural resource firms are under-represented. The lack of natural resource firms reflects, in part, the fact that we drop many large multinational firms in the extraction industry (oil). We highlight also that transportation and utilities contribute a share more in line with that in the non-disclosing universe.

Next, it is instructive to compare employment in our merged sample with Compustat's measure of employment for the firms in our sample. To this end, we use the end-of-fiscal-year observations in our merged sample because employment data are only available annually in Compustat. We first regress log employment in our sample on log Compustat employment. Table 2 reports results. The coefficient on Compustat employment is 0.87, and the R^2 is 0.82. In column 2, we restrict the sample to firms that are domestically oriented. This subsample consists of about 450 firms that appear to have the vast majority of their activities in the United States, based on their annual reports. (Appendix A discusses this designation in more detail.) The coefficient on log Compustat employment increases to almost 0.94, and the R^2 is now 0.90.

These results are based on a pooled sample and reflect, at least in part, the fact that large firms in our merged data are also large in Compustat. If we include firm fixed effects and thus restrict attention to only within-firm variation, the quality of the fit deteriorates, of course. In the sample of domestically oriented firms, the coefficient falls to about 0.65 (see column 4 in Table 2). Two possible reasons lie behind this result. First, as noted above, several large states do not grant access to their data in the LDE. Second, Compustat's measures of annual employment may be quite noisy. Baumol, Blinder, and Wolff (2005) remark that a referee of their manuscript cautioned against using Compustat data to study corporate downsizing, because Compustat's measure of the change in employment "did not match up well with census administrative" data.

2.3. Labor earnings behavior

In this section, we describe the relation between average labor earnings and other firm characteristics, especially leverage. Average labor earnings is calculated as total payroll divided by employment. We refer to this variable as "earnings" rather than the "wage" because we do not have data on hours worked.

Table 3 collects a few summary statistics to this end. Panel A shows that more highly levered firms in our data pay lower labor earnings. In particular, firms whose average leverage is in the bottom one-third of the distribution pay almost 9% higher labor earnings relative to firms in the middle tier of the leverage distribution (whose leverage is between the 33rd and 67th percentiles). But the gradient flattens at high leverage: firms in the top one-third of the leverage distribution pay only slightly lower labor earnings than firms in the middle tier.

High leverage reflects liabilities relative to assets. We also summarize the relation between labor earnings and assets, specifically. Larger firms, as measured by their average assets, pay higher labor earnings (panel B). In particular, firms in the top one-third of the assets distribution pay 15% higher labor earnings than firms in the middle tier (between the 33rd and 67th percentiles). Interestingly, the smallest firms—those in the bottom one-third of the asset distribution—also pay 6.5% higher labor earnings than those in the middle tier.

To distinguish between the effects of size and leverage, we next regress average labor earnings on a dummy equal to 1 if the firm's average assets are less than the median assets; a dummy equal 1 if the firm's average leverage is greater than the median; and an interaction of the two. The coefficient on the interaction measures the log average labor earnings at firms whose leverage is high (greater than the median) and whose assets are low (less than the median). It follows that the coefficient on the leverage dummy alone measures the log average labor earnings at firms whose leverage is high but whose assets are also high, and the coefficient on the assets dummy alone measures the log average labor earnings at firms whose leverage is low but whose assets are also low. Lastly, the intercept measures the log average labor earnings at firms whose leverage is low and whose assets are high. This is latter group is the reference point; all other groups' labor earnings are expressed relative to this reference.

Panel C of Table 3 reports results. Comparing labor earnings among larger firms (that is, controlling for size), the more highly levered pay 7.6% lower labor earnings. Thus, higher leverage is associated with lower labor earnings. Next, comparing labor earnings among less levered firms (that is, controlling for leverage), the smaller firms pay 5.4% lower labor earnings. Recalling panel B, this was not a foregone conclusion: the smallest firms (in the bottom tercile of the distribution) actually pay higher labor earnings. These high-labor earnings small firms must be concentrated, then, among the *more* levered companies. The final quadrant of panel C confirms this conjecture. It shows that small and highly levered companies do not pay lower labor earnings than large and less levered firms. As noted, this pattern reflects two off-setting factors: higher leverage is uniformly associated with lower labor earnings, but there are some especially small firms that pay high labor earnings.

Next, we explore the co-movement of average labor earnings with firms' factor demands and financial positions. We begin by projecting log average labor earnings on one-period lagged log employment; lagged log capital; lagged leverage; and current log sales. We also include firm fixed effects and, if the period corresponds to a calendar quarter, seasonal dummies are included (unless otherwise noted).

Table 4 summarizes our findings. Column 1 contains our baseline specification just described. Lagged employment enters negatively, although it is estimated imprecisely. The point estimate says that, if a firm's employment is temporarily high, average labor earnings are (temporarily) low conditional on capital and productivity. This finding can be read as evidence consistent with decreasing returns.

Next, a 10% increase in sales increases average labor earnings by 0.5%. The positive coefficient on sales is consistent with a rent-sharing arrangement in which the surplus from the worker-firm match is shared between the two. Card, Devicienti, and Maida (2014) stress, however, that these estimates are likely a lower bound on rent-sharing, because a good deal of high-frequency variation in sales does not pass to average labor earnings if the latter are smoothed.

Interestingly, the coefficient on capital in our baseline regression is also positive. Card et al. (2014) argue that result this is consistent with positive hold-up power among workers. Intuitively, after capital is sunk, workers who are complementary to capital can extract greater rents. This hold-up power is indeed incorporated in the wage bargaining protocol we use in our dynamic model.

Lastly, the coefficient on lagged leverage (the debt to asset ratio) is negative and significant. Quantitatively, this result implies that a 20 percentage point increase in debt relative to assets—roughly, a one standard deviation shift—reduces average labor earnings by almost 3%. We are not aware of comparable estimates in the literature of this reduced-form effect. Our result is nonetheless consistent with evidence from smaller samples that unions yield concessions when the firm is under pronounced financial distress. See, for instance, Benmelech, Bergman, and Enriquez (2012), who study the airline industry.

Later in the paper, we interpret this in the context of a bargaining game in which high leverage implies a higher probability of default, all else equal. This higher default probability reduces the expected marginal value of a worker and thus leads to a lower wage.

The remainder of the columns in Table 4 presents results for variants on our baseline specification. The results are largely unchanged. In column 2, we confine the sample to the domestically oriented firms but find that little changes. In columns 3-5, we investigate the correlation between labor earnings and leverage in more detail. In column 3, we inspect whether the effect of leverage differs across sectors. In column 4, we ask if the effect of leverage is amplified at smaller firms (in terms of assets). And in column 5, leverage is interacted with log sales.

Our findings are the following. First, the negative association between labor earnings and leverage appears to be slightly stronger in the service sector, although the difference is marginally significant.[5] Second, the interaction between leverage and size (assets) is positive, although imprecisely estimated. The sign on this interaction may reflect our findings in Table 3, namely, the negative association between leverage and labor earnings is concentrated among mature (that is, larger) enterprises. Third, the interaction between leverage and sales is an especially salient addition to the regression. The point estimate says that the marginal effect of higher sales weakens at highly levered firms. Put another way, high leverage attenuates the extent of rent-sharing. This finding appears to be consistent with our structural model, where high leverage predicts a higher probability of default. As a result, any given increase in sales is more likely to accrue to debtholders rather than shareholders, and so has less of a positive effect on the wage.

Table 4 includes two more specifications. Column 6 adds quarterly time dummies to control for aggregate fluctuations. This addition has relatively little effect on our results, which is indicative of the size of idiosyncratic relative to aggregate variation. The only coefficient that is notably affected is that on sales, which remains positive but is now estimated more imprecisely. In Column 7, we use annual data, specifically, end of fiscal year observations. We include year effects again to control for aggregate fluctuations. Here, the coefficients are all of the same sign as in our baseline, and are estimated more precisely. In particular, the coefficient on sales is significant, despite the presence of the year effects.

For the sake of completeness, we repeat these regressions for log employment as the outcome variable. These results are shown in the Table 5. The main difference between the employment and labor earnings results has to do with the role of leverage, which plays a far weaker role in accounting for high frequency employment dynamics. We find two exceptions to this general pattern. First, quarterly employment does appear to decline in the goods

[5] The goods sector is defined as including mining, construction, and manufacturing (SIC categories between 10 and 39).

sector when leverage is high, but the effect is marginally significant. Second, when we use annual data, the coefficient on leverage is negative and marginally statistically significant in the full sample.

These findings may suggest that adjustment frictions in employment dampen its reaction to leverage relative to the response of labor earnings. The latter's reaction, in turn, likely reflects at least in part variation in hours per worker; the latter could be the margin on which firms move first when their debt capacity becomes more limited. Given our data, however, it is hard to disentangle the sources of labor earnings movements—the portion due to hours as opposed to the portion due to wage rates. Georgiadis and Manning (2014) confront the same issue in examining average firm-level labor earnings in the United Kingdom. They consider several reasons for the extent of high-frequency variation in labor earnings and conclude that some of it likely reflects flexibility in wage rates.

Next, we further explore the negative association between leverage and labor earnings, in particular, examining different groups of firms stratified according to whether they have an investment grade bond rating, a junk bond rating, or no rating at all. The results are in Table 6. Interestingly, we find that the coefficient on lagged leverage is insignificantly different from zero for both groups of firms that have bond ratings. The coefficient even flips sign in the sample of junk-bond firms, although the sample size is tiny. In contrast, the coefficient in the sample of firms without bond ratings remains negative and significant. This finding is suggestive of a world in which financial frictions are important for the ways in which a firm's leverage mediates its bargaining with labor over their earnings.

To conclude, we run the same labor earnings regressions using the sub-sample of Compustat firms that disclose this information. Average labor earnings is constructed by dividing item XLR (total staff expenses) by total employment. It is instructive to compare the Compustat findings with the findings from our merged panel. Confining the years to our sample period, the Compustat data are too noisy to make any inferences, as shown in Column 2 of Table 8. (For comparison, Column 1 of Table 8 restates results in our BLS sample with annual data—see column 7 in Table 4.) The coefficient on lagged leverage is negative, but insignificantly different from zero. Indeed, all of the coefficients are insignificant. Stretching the Compustat the sample back to 1970 adds 14,000 observations. In this case, the coefficients on lagged capital and current sales are now each significantly positive, and the coefficient on lagged employment is significantly negative. Each of these parallels our findings using our BLS data. However, the coefficient on lagged leverage is positive and insignificantly different from zero.[6] This result may reflect the fact that disclosing firms are vastly larger companies on average, where variation in leverage is less likely to make financial constraints bind.

3. Theory

In this section, we introduce the firm's problem and discuss how the interest and wage rates are determined.

3.1. Optimization problem

We consider an infinitely lived firm in discrete time. At each period, the firm's risk-neutral manager chooses new factor demands and how to finance these purchases, with the goal of maximizing the present value of after-tax cash flows to shareholders. Specifically, at the beginning of each period, the firm chooses the levels of capital, k, and employment, n, that will be used in production at the beginning of *next* period. Output, y is give by a standard Cobb-Douglas production function: $y = z'k^{\alpha}n^{\beta}$. We assume that all of the factors must be compensated when hired. This assumption implies that the firm chooses and compensates its factors before it knows the level of productivity, z', that will prevail when production, y',

[6] Controlling for firm fixed effects is important here. Omitting these in favor of industry fixed effects yields a negative leverage coefficient that is significant at the 5% level. This latter regression picks up the negative correlation in the *cross section* of firms between average labor earnings and leverage, rather than the effect of varying leverage for a given firm.

is undertaken at the start of next period, which is indicated by a prime.

The idiosyncratic productivity draw, z, follows an $AR(1)$ process in logs:

$$\ln(z') = \rho \ln(z) + \varepsilon', \tag{1}$$

in which ρ is the autocorrelation coefficient, and ε' is an $i.i.d.$, random variable with a normal distribution. It has a mean of 0 and a variance of σ.

To finance its factor demands, the firm can issue one-period, defaultable debt, b, at rate $\tilde{r}$, which is determined by the lender's zero-profit condition, as we outline below. If instead the firm opts to save, which means $b < 0$, it has access to a safe asset that pays a constant rate of return, $\bar{r}$. Thus the interest rate on debt can be expressed as

$$r = \begin{cases} \tilde{r} & \text{if} \quad b > 0 \\ \bar{r} & \text{if} \quad b \leq 0 \end{cases}$$

The firm can also distribute excess funds to shareholders or raise funds from shareholders in the equity market. Distributions are the difference between the inflow and outflow of resources to the firm. Cash inflows equal the proceeds of debt sales, b, plus the firm's (liquid) internal funds at the beginning of the period, denoted by ω_{-1}. We define ω as after-tax revenue (realized at the start of next period) less the debt obligation that comes due:

$$\omega = z' k^{\alpha} n^{\beta} - (1 + r) b. \tag{2}$$

The outflow of resources from the firm equals the sum of factor payments and the expenses of factor adjustment. Factor payments include the cost of investment and the wage bill, W, which, as we explain below, is determined as the outcome of a bargaining game. We normalize the price of the capital good to 1, so the cost of purchasing $i \equiv k - (1 - \delta) k_{-1}$ units of capital is just i if $i \geq 0$. If the firm sells (used) equipment, we assume it cannot recover the full purchase price. This assumption may reflect a lemons problem, that is, buyers require a discount because the quality of used equipment is uncertain. Machinery might also be highly customized to a firm's operations, so it has limited value on a secondary market. Accordingly, in the case of a sale, the firm earns $-c^k i$ if $i < 0$, with $c^k \in (0,1)$. Therefore, the cost of investment is given by

$$R(i) \equiv i \cdot \mathbf{1}_{[i \geq 0]} + c^k i \cdot \mathbf{1}\left[i < 0\right].$$

In addition, the firm bears the cost of adjusting labor by Δn units, denoted by $C(\Delta n)$. We allow $C(\Delta n)$ to take a simple proportional form,

$$C(\Delta n) \equiv c^n \Delta n \cdot \mathbf{1}_{[\Delta n > 0]}$$

with c^n representing the per-capita cost of hiring. Putting these pieces together, the distribution before fees is

$$D = \omega_{-1} + b - W\left(k, n, \omega, z'\right) - R(i) - C(\Delta n). \tag{3}$$

Negative distributions are interpreted as equity issuance and subject to underwriting fees. If $D < 0$, the firm incurs an underwriting fee of the form, $\Lambda^{-}(D) \equiv \lambda_0 + \lambda_1 \left|D\right|$. Hence, the real after-fee distributions are:

$$\hat{D} \equiv D - \Lambda^{-}(D)\mathbf{1}_{[D<0]}.$$

The cost of issuing equity is especially important in the analysis. As noted in Hennessy and Whited (2007), costly equity issuance supports a pecking-order structure of financing. This point is particularly easy to see if $\lambda_0 > 0$. To avoid the fixed cost of equity financing, the firm issues debt to fill relatively modest funding gaps (differences between its factor demands and its internal funds). It turns to equity financing as a last resort, in response to a rising interest rate on debt.

Let r_F be the rate at which the firm discounts its cash flows. We assume that $r_F > \bar{r}$. This assumption is a simple way of capturing the tax benefit of debt. Essentially, both this assumption and a standard tax benefit render the firm impatient relative to interest rate it pays on its debt, and this impatience is the key force in this class of models that induces the firm to hold debt on its balance sheet.

The firm's optimization problem can now be characterized recursively by the Bellman equation,

$$\Pi\left(k_{-1}, n_{-1}, \omega_{-1}, z\right) = \max_{b,k,n} \left\{ \hat{D} + \frac{1}{1+r_F} \int \Pi\left(k, n, \omega, z'\right) \mathrm{d}G\left(z' | z\right) \right\}, \tag{4}$$

where G is the conditional distribution of next-period productivity given the present z, implied by (1).

This problem is solved taking account of the cost of debt finance, r, and the wage bargain, W, as well as the evolution of internal funds. Thus, the firm's choices of b, k, and n influence both r and W (though this dependence has been suppressed in writing r and W to reduce clutter). The loan and wage contracting problems are detailed in the following two sections.

Before turning to the interest contracting problem, it is worth highlighting why labor, which has been relatively neglected in studies of financing frictions, is subject to a financing constraint in this setting. There are two reasons. The first derives from the observation that sales tend to be scattered over a quarter or year whereas labor in particular must be paid at fixed, regular intervals. For this reason, we assume here that all factors must be financed before the revenue from sales is realized. As a result, lenders face default risk, as the firm may be unable, after the realization of z', to repay what it borrowed to finance payroll and capital expenditures. Second, labor is treated as quasi-fixed factor. Accordingly, even if the firm could wait to finance its payroll with internal funds, costs of adjusting labor might induce it to sustain a level of employment over and above what is warranted—and what can be financed—by current profitability. This behavior can spur the firm to take on some default risk in order to borrow its way through (temporarily) bad times. If neither of these features is present, financing frictions do not bind on labor under decreasing returns (Ejarque 2002). The reason is that the firm earns a surplus from its employment of labor, so it can finance the (statically) optimal choice using realized sales.

3.2. Loan contract

We assume the firm can sign a one-period loan contract with a perfectly competitive financial intermediary. In the event that the firm is unable to repay, the lender can seize a fraction, $1 - \xi$, of the firm's fixed assets, that is, its resalable capital. The share $\xi \in (0, 1)$ can be thought of as a (deadweight) cost of processing the bankruptcy. This contract is inspired by the debt contract that emerges in the seminal costly state verification model in Townsend (1979) and later adapted by Bernanke and Gertler (1989).[7]

What triggers a default? Hennessy and Whited (2007) note that lenders can extend credit as long as the firm has positive present (market) value. In that case, bondholders can at least obtain shares of the firm as part of a bankruptcy settlement. However, firms do retain some control over the pace of bankruptcy proceedings, and can use this leverage to induce creditors to partially waive their rights to new shares in exchange for accelerating the settlement Franks and Torous (1989). As a technical matter, moreover, suppressing negotiation over new shares simplifies the interest-rate contracting problem.

Accordingly, following Gilchrist et al. (2013), we assume the firm is unable to borrow against its expected future market value. This assumption means that the firm cannot roll over its debt if its current net worth turns negative. Net worth in this setting equals the

[7] We depart from Townsend (1979) in that shocks, z, are persistent. Hence, if a lender did not know z, it could in principle learn it from observed choices of k and n. Rather than solve this problem, we assume z is common knowledge but assert that state-contingent contracts are infeasible. This approach follows, among others, Hennessy and Whited (2007) and Gilchrist et al. (2013).

firm's internal funds, ω, plus the collateralizable value of its (non-depreciated) capital, where $1-\xi$ represents the fraction of of the capital stock that can be seized by lenders in default. Noting from (2) that ω is increasing in z', one can define a threshold level of productivity, $\hat{z}$, such that the firm that has chosen the tuple (b, k, n) defaults next period if $z' < \hat{z}$:

$$0 \equiv \hat{z} k^{\alpha} n^{\beta} - (1+r)\, b + (1-\xi)\,(1-\delta)\, k, \tag{5}$$

The default threshold, $\hat{z}$, represents one component of the loan contract.

The second element of the contract is the rate of interest, r, which is pinned down by an expected zero profit condition that must hold under free entry. We construct this condition as follows. The payoff to the lender in the event of default is after-tax revenue plus a share, $1-\xi$, of the undepreciated capital stock. Note that firms in the United States are typically forbidden from claiming an interest deduction in the case of default. Hence, we evaluate the tax liability in default as if $b = 0$. The payoff outside of default is simply the after-tax interest payment. Under free entry, the expected payoff from a risky loan equals the payoff from a risk-free loan at rate $\bar{r}$. Therefore, r satisfies:

$$\int_0^{\hat{z}} \left[z' k^{\alpha} n^{\beta} + (1-\xi)\,(1-\delta)\, k \right] dG\,(z'|z) + (1 - G\,(\hat{z}|z))\,(1+r)\, b = (1+\bar{r})\, b. \tag{6}$$

For a given (b, k, n, z), equations (5) and (6) pin down the loan contract, $(r, \hat{z})$. The effect of each argument on the contract is intuitive. For any (k, n, z), r is increasing in b, reflecting the rising default risk. As illustrated in Figure 1, this interest rate schedule shifts down if either k, n, or z rises, in part because each portends greater future output that can be sold to repay the lender. Hence, each reduces the riskiness of the loan. Taking account of these effects, the firm will choose (b, k, n) at the outset of the period to solve the problem (4).

3.3. Wage bargaining

We introduce bargaining for two reasons. First, the dynamics of firm-level employment suggest the presence of certain labor adjustment costs, which in turn imply the existence of rents to ongoing firm-worker matches. These rents have to be divided, and the bargaining protocol due to Stole and Zwiebel (1996) provides a tractable way to do so. Second, there is evidence that highly indebted firms, which face a relatively high risk of default, can negotiate lower wages; see Benmelech et al. (2012) and citations therein. This evidence suggests that firms can use the wage bargain to relax its financing constraint. As such, wage setting is an important element of the firm's problem. We now sketch the solution to the bargaining game.

Consider a firm that has just completed its desired labor adjustment and has a workforce of size n. It now plays a non-cooperative bargaining game with its workers. Under the protocol, any one worker can request a pairwise bargaining session with the firm, and vice versa. If a wage is agreed, the two divide the marginal surplus implied by their joint production, with the worker receiving a constant share, ψ. Note that the marginal surplus is calculated taking as given the participation of the remaining workers. This calculation reflects the assumption that individual workers are unable to coordinate their decisions to stay or quit. If a wage is not agreed, the worker exits and enjoys a flow payoff from non-employment—reflecting, for instance, the flow value of leisure—equal to μ. The marginal contribution of the remaining workers is affected by his departure because there are decreasing returns to scale. Accordingly, the remaining workers will request a bargaining session to revise their agreements.

As detailed in Appendix B, the solution to this game is the following.

Proposition 1 *The wage bargain is characterized by a differential equation for the wage* *bill,* $W(k,n,\omega,z')$*:*

$$(1-\psi)\frac{W(k,n,\omega,z')}{n}+\psi\frac{\partial W(k,n,\omega,z')}{\partial n}=\psi\left(\frac{1}{1+\bar{r}}\right)\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right]+(1-\psi)\mu, \tag{7}$$

where

$$\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right]\equiv\int_{\hat{z}}\frac{\partial\omega(k,n,\omega,z')}{\partial n}\mathrm{d}G(z'|z)$$

is the expected marginal effect of today's labor on next period's net worth, ω*, as implied by (2).*

The lower limit of integration here is the default threshold, $\hat{z}$ because the worker's contribution in the default regime is zero, with all assets being seized by the lender.

The economics of (7) are straightforward. The left side consists of two parts. The first is the wage rate, $\frac{W(k,n,\omega,z')}{n}$, paid to the new hire. The second component, $\frac{\partial W(k,n,\omega,z')}{\partial n}$, reflects the marginal effect of a new hire on the (pre-existing) wage bill of his co-workers. The latter term enters because of decreasing returns, which implies the marginal product is declining in n. Hence, the hiring of a worker forces a downward revision to the pre-existing wage rate. Putting these two components together, the weighted average of $\frac{\partial W(k,n,\omega,z')}{\partial n}$ and $\frac{W(k,n,\omega,z')}{n}$ on the left side can be thought of as the marginal wage. The right side says that the worker's compensation reflects a weighted average of his outside option, μ, and his contribution to the firm's cash flow, as measured by $\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right]$. This form is clearly reminiscent of the standard Nash bargain.

Equation (7) simplifies if the firm chooses not to borrow. Indeed, one can use the definition of ω in (2) to confirm that if the firm chooses to save—so the interest rate is $\bar{r}$, independent of the firm's factor demands—then (7) collapses to the familiar wage bargain in Stole and Zwiebel (1996), where the wage bill is, roughly speaking, a weighted sum of a worker's productivity and his outside option. The solution in this special case resembles that presented in Acemoglu and Hawkins (2014) and Elsby and Michaels (2013), except that a worker's productivity in our setting with capital is also conditioned on k.

However, if the firm borrows, then its choice of n affects expected internal funds via the financing friction. Fortunately, characterizing $\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right]$ is straightforward under the following condition.

Assumption 1 *The loan contract is determined before the wage bargain and is* fixed *as of the time of bargaining.*

This assumption is also adopted by Monacelli et al. (2011) in a related bargaining problem, though the latter studies a more stylized setting featuring constant returns and omitting idiosyncratic productivity and endogenous separations.

This timing convention seems consistent with the fact that interest rates on (all but very short term) debt are typically revised less often than wages. Making use of equation (2), it follows that $\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right] = \mathcal{Z}(n)\,\beta k^{\alpha} n^{\beta-1}$, where $\mathcal{Z}(n) \equiv \int_{\hat{z}((k,n,\omega,z')} z'\mathrm{d}G(z'|z)$ denotes the expected value of z' (that a firm can appropriate) after accounting for the risk of default.

Substituting for $\mathbb{E}\left[\frac{\partial\omega(k,n,\omega,z')}{\partial n}\right]$ in (7), we have:

Corollary 1 *The solution to (7) is the wage bill,*

$$W(k,n,\omega,z') = \left(\frac{1}{1+\bar{r}(1-\tau_i)}\right) n^{-\bar{\psi}} \int_0^n \mathcal{Z}(\nu)\,\beta k^{\alpha}\nu^{\beta-1+\bar{\psi}}\mathrm{d}\nu + (1-\psi)\,\mu n, \qquad (8)$$

where $\bar{\psi} \equiv (1-\psi)/\psi$.

There are a few observations to make about (8). First, the integral has a natural economic interpretation, which can be seen by considering what happens if a worker leaves a firm of size n. This one exit increases the expected marginal product of the other $n-1$ workers, enabling them to bargain for higher wages. However, at this point any of the remaining $n-1$ workers are also free to leave, and an exit would increase the marginal products of the other $n-2$ workers, and so on. Thus, a worker's departure would set off a chain of renegotiations, with the wage rise rising at each node because of the increasing marginal product of labor.

As a result, any worker is able to "hold up" the firm to demand a portion of all of these infra-margins of production. The sum of these infra-margins is the integral in (8). The other component of (8) is the outside option. The worker obtains a weighted sum of these two elements.

Second, evaluating $\mathcal{Z}$ inside the integral in (8) turns out to require a little care. To see this issue, we must briefly delve into the bargaining protocol in more detail. Although workers will not in fact quit, the protocol reflects how the wage bargain would respond in such "off-equilibrium" events. To that end, suppose a mass of employees did leave a firm that entered the bargaining session with n workers. Because output would fall, the probability of default would increase, even with a fixed interest rate. In particular, the default threshold used to update $\mathcal{Z}(\nu)$ at $\nu < n$ must rise. Specifically, we have that $\mathcal{Z}(\nu) \equiv \int_{\hat{z}(b,k,\nu,z)} z' \mathrm{d}G(z'|z)$, where the threshold, $\hat{z}$, is updated according to (5) *but now taking r as given*:

$$0 \equiv \hat{z}(b,k,\nu)\, k^{\alpha} n^{\beta} - (1+r)\, b + (1-\xi)(1-\delta)\, k. \tag{9}$$

The simplicity of the updating rule (9) for "off-equilibrium" moves is another advantage of assuming that the interest rate contract is fixed before bargaining. Accordingly, note that r in (9) is conditioned on the planned (and, in equilibrium, realized) level of employment, n.

Third, and most important, equations (8)-(9) help reveal the effect of financing constraints on the wage bargain. Suppose a firm has already agreed to a loan contract such that it is highly leveraged, that is, b is large. From (9), this situation implies a higher probability of default, so $\hat{z}$ is higher and $\mathcal{Z}$ is lower for any ν. As a result, the expected contribution of a worker to the firm's cash flow, as captured by the integral in (8), is diminished. This bargaining outcome translates in (8) to a lower wage, as illustrated in Figure 2.[8]

We now summarize the events discussed thus far in Section 3. We begin with the final

[8] This result is reminiscent of the result in Perotti and Spier (1993) that outstanding leverage can affect the renegotiation of senior claims. However, our model is more specific to the labor setting, as their model does not allow any separation between quantities and prices embodied in the senior claim, and their senior claim is not necessarily a factor of production.

event of the period, bargaining. The firm and workers bargain, taking as given r. The firm offers a wage that recognizes the hold-up problem, and relationships with all n workers are preserved. Now we take one step back. The intermediary foresees the bargaining problem and its resolution. Conditional on this expectation, it agrees to an interest rate r consistent with firm's proposed plans as summarized in the vector, (b, k, n). Note that the lender recognizes that suppressing renegotiation of r during wage bargaining will not bind: the firm's plans will be implemented as scheduled, so no news will arrive that would disturb the initial interest rate contract. Taking one more step back, the firm recognizes the prices r and W it will pay, and chooses (b, k, n) optimally.

4. Estimation

We estimate the model parameters using the method of simulated moments. This procedure identifies values of the structural parameters that generate outcomes within the model that most closely fit their empirical counterparts. In what follows, we first review the mechanics of the model solution, simulation, and estimation. We note that the solution is conditioned on a number of parameters whose values are chosen based on information outside of the theory. These parameterizations are discussed here. Next, we review the sample moments used in estimation and relate the intuition behind why these moments help identify the structural parameters. We then summarize results for our current specification.

4.1. Model solution

We solve the model via value function iteration. The grid and transition matrix for the productivity shock, z, are formed using the method in Tauchen (1986). Grids for capital and labor are formed to span the range of optimal choices in the simulation. For each triple of labor, capital, and productivity, a grid for net debt is formed. The net debt grid is specialized because the triple (k, n, z) determines a maximum feasible level of debt, beyond which the probability of default is too high to induce the lender to make a loan at any rate. The lower support of the debt grid is chosen so that it binds only rarely (if at all) in the simulations.

The mechanics of the estimation are straightforward. For a given set of parameters, the model is solved and simulated. In particular, we simulate a panel comparable in size to what we have in the merged LDE-Compustat dataset and calculate a set of moments (detailed below). Based on the distance between model-generated moments and their empirical counterparts, the values of the structural parameters are updated. We use the genetic differential evolution algorithm to update the parameters and search for a better fit.

A number of parameters in our model can be easily pinned down based on information outside of our merged panel. Thus, these parameters are not estimated. We set the risk-free rate, $\bar{r}$, to 2.5% on an annualized basis, in line with historical evidence. Next, we estimate λ_0 and λ_1 using a regression of issuance fees on issuance proceeds, where we scale both of these variables by total firm assets. The slope of the regression is an estimate of λ_1. To obtain an estimate of λ_0, we multiply the regression intercept by the steady state capital stock from the model simulation. We make two further simplifications. First, we set the outsize option, μ equal to the user cost of capital. The motivation is that in a frictionless market, the marginal products of labor and capital equal each other, and both equal the user cost. Second, we assume the firing costs are equal to zero.[9] These choices leave us with 9 structural parameters to be estimated: $\left\{\alpha, \beta, \delta, \rho, \psi, \sigma, c^k, c^n, \xi\right\}$.

4.2. Identification

Although all of the model parameters affect all of the moments we use in our estimation, the dependence of some parameters on a particular set of moments is sufficiently pronounced that we can provide intuition for how these moments inform and identify our parameters. For example, ρ and σ are easily identified by including in the list of moments the serial

[9]This assumption is based on the fact that aside from premiums related unemployment insurance, firing costs in the United States are likely negligible.

correlation and residual standard deviation of an autoregression of the log of sales. We estimate this autoregression using the technique in Han and Phillips (2010), which allows for firm-specific intercepts and time trends.

The rate of depreciation, δ is identified by including the mean of investment because in the steady state. Although the partial reversibility in the model will cause the firm to deviate from its frictionless investment policy, the firm's investment is, on average, enough to replace depreciated capital.

Next, the variances of the factor demand distributions speak to the size of frictions on factor adjustment, c^k and c^n. The cost of firing/hiring, for instance, attenuates the dispersion in employment growth, making the latter moment especially informative about this adjustment cost. Similarly, the lower c^k, the greater the inaction range for optimal investment and the lower the standard deviation of investment. We also include the covariance between employment growth and investment to assist in the identification of the factor demand frictions. If c^k is large relative to c^n, for instance, then the firm "leans" on employment more, so that joint adjustments of labor and capital are infrequent. Hence, the covariance is smaller.

Our external financing moments include average leverage, which we measure as the difference between long term debt plus debt in current liabilities less cash-equivalent assets, all divided by total assets. This netting off of liquid assets is a common approach in the literature to identifying a notion of debt that maps most cleanly to that in the model, where b represents the firm's net financial position. Viewed through the lens of our model, this moment reflects several salient parameters. For example, high leverage is deterred by the size of the bankruptcy cost, ξ, which implies a lower repayment in default, thus amplifying risk premia and reducing demand for debt. In addition, the demand for debt is stimulated by the precautionary savings motive, which is increasing in the extent of idiosyncratic risk (the variance of z).

We also include in our list of moments average equity issuance, which we measure as the total proceeds from SEOs and private placements from the Security Data Corporation

(SDC) database. Because we estimate issuance costs outside the model, this moment serves in part as an external validation of the model.

Next we include three moments that can help identify the bargaining parameter, ψ and the production function parameter β. Mean wages as a fraction of operating income is clearly related to labor's share and, accordingly, helps inform the choice of β. The primary moment used to identify ψ is the wage elasticity to sales, defined simply as the coefficient from regression labor earnings on sales. If bargaining power is high, workers gain a larger share of sales, so the covariance between these two variables increases.

4.3. Baseline results

We now summarize our baseline results. In Panel A, we report the actual data moments and the model simulated moments. Because of our large sample size, four of the fourteen moment pairs are significantly different from one another, but few are economically different, and several of these pairs match up nicely. Actual and simulated investment are nearly identical, as are the standard deviation of investment and the wage elasticity to sales. We only see a few instances in which the simulated and actual moments differ by a factor of two or more. In particular, the model markedly misses the standard deviation of employment growth and the standard deviation of the change in log sales.

Next, we turn to the parameter estimates. In many cases, these seem comparable to related estimates in the literature. For instance, the estimates of the standard deviation and serial correlation of the driving process, z, are in line with the estimates in Hennessy and Whited (2007). The parameter ξ is in line with the estimates of the collateral parameter in Li, Whited, and Wu (2016). Recall that our default threshold is essentially a net worth covenant, so one interpretation of ξ is the fraction of the capital stock that can be surrendered to the lender in default as collateral. In contrast, some parameters are not in accord with important studies in the rest of the literature. For instance, our estimate of the employment adjustment cost is considerably larger than those from Bloom (2009). In contrast, at 85%, our estimate of the resale price of capital is only somewhat higher than the 66% resale price from Bloom (2009).

5. Implications

We can now assess the estimated model's ability to engage recent reduced-form evidence on financing constraints. First, we examine whether the model can match the sensitivity of wages to leverage that we observe in our data. We find that it does. Recall that in the data we find that log labor earnings decrease by 0.14 in response to a one percentage point increase in leverage, while log employment does not move. In our model, we find a very low sensitivity of -0.0002 for employment and a comparable sensitivity of -0.231 for labor earnings. These results are of interest in part because they constitute an out-of-sample test of the model, as neither of these features of the data was used in the estimation of the model.

Next we use the model to examine the economic forces that lead to these results. To this end, we conduct several comparative statics exercises, which can be found in Figure **??**, which shows how the sensitivities of employment and labor earnings change with respect to three key model parameters: labor bargaining power, ψ, hiring adjustment costs, c_n, and the deadweight cost of default, ξ. Each panel is constructed as follows. First, we set all model parameters equal to their values from our estimation. Next, one at a time, we change a model parameter, solve the model, and recalculate the relevant sensitivity. Each panel depicts the relation between the relevant sensitivity and the corresponding model parameters.

We first examine the sensitivity of employment to leverage, finding several intuitive results. The sensitivity of employment to leverage declines in absolute value with ψ, the labor bargaining power parameter. A higher ψ means a more flexible wage. As can be seen in (8), as bargaining power increases, the fixed outside option becomes a less important component of the wage bill. This flexibility attenuates changes in labor demand that might arise from debt overhang considerations. Next, the sensitivity of employment to leverage naturally declines in absolute value with c_n, the cost of hiring. Finally, this sensitivity declines in absolute value with the parameter ξ, which can be interpreted either as a deadweight default cost or the fraction of the capital stock that cannot be collateralized. Here, the intuition is that as this parameter rises, the use of leverage declines. With less access to external finance in general, the firm's policies become less responsive to productivity shocks, so the sensitivity to leverage naturally declines.

Next, we turn to the sensitivity of labor earnings to leverage. Here, as bargaining power increases, wages become more flexible, which naturally steepens the negative relation between leverage and wages that stems from the wage bargain in (8). An increase in the cost of hiring also naturally boosts the sensitivity of labor earnings to leverage, as employment becomes less flexible. Finally, as in the case of employment this sensitivity also decreases in absolute value as the access to debt financing decreases.

Our second experiment is motivated not by our own results by by evidence of financing constraints from the 2008-09 financial crisis. Chodorow-Reich (2014) considers the experiences of firms whose intermediaries suffered the largest declines in lending capacity. For instance, banks that happened to be more heavily invested in mortgage-related securities saw their net worth decline significantly. This, in turn, reduced their capacity for making risky loans. Chodorow-Reich (2014) finds that firms that had a history of borrowing from these intermediaries reduce employment more than comparable firms that had long-standing ties to"healthier" lenders.

We implement this idea within our model in the following way. Again, we first simulate the model to recover the steady state distributions, at which point a random sample of half of the firms are unexpectedly paired with a lender whose cost of funds is higher than the risk-free rate. These firms (re)-solve their optimal factor demand rules in the face of the new interest rate schedules. The model's implied treatment effect is then measured by comparing the outcomes across the two halves of the sample, one facing a healthy lender and the other not. The unhealthy lender is assumed to face a cost of funds 50 basis points higher than his healthier counterpart. In other words, we raise $\bar{r}$ among the unhealthy lender by 50 basis points. This spread is consistent with the evidence in Chodorow-Reich (2014) regarding the interest rates paid by firms with relatively unhealthy lenders.

The results from this counterfactual experiment are in Table 10, which shows that the model nearly exactly replicates the 5.5% drop in employment documented in Chodorow-Reich (2014). In addition, we find an even larger decrease in labor earnings, consistent with the revenue sharing implied by the labor bargain. Finally, we find a modest decrease in the capital stock, which stems from the resale discount on capital goods.

6. Conclusion

We have sought a quantitative answer to the questions of whether, how, and why financing frictions affect labor demand. Answering this question in a satisfying manner is challenging for several reasons. Labor demand interacts in important ways with the demand for other quasi-fixed factors, in particular, capital. And unlike the case of capital, it is unrealistic to assume that firms are price takers in the labor market. To approach this question while addressing these hurdles, we formulate and estimate a model of labor and capital demand that incorporates realistic adjustment frictions, financial frictions, and wage bargaining. To estimate the model's parameters, we assemble a new data set by merging standard balance sheet and income statement information from Compustat with establishment level data on employment and the wage bill from the Bureau of Labor Statistics. We find that the model can match several relevant features of the data.

We also find that our model can replicate the sensitivity of factor demand to exogenous movements in cash flows and interest rates that have been found previously in the data. We then use the model to understand the economics behind these sensitivities. Interestingly, many factors besides financial frictions affect observed sensitivities of both labor and capital demand to these exogenous shocks. The obvious conclusion is that the response of factor demands to exogenous shocks need not be indicative of financial frictions. In particular, labor bargaining power has a strong affect on the sensitivity of labor demand to cash flows, as it affects both wage stickiness and optimal leverage decisions.

We view the outcome of our research as providing a microeconomic foundation for aggregate equilibrium analysis. An understanding of financing constraints in aggregate equilibrium is vital to our interpretation of aggregate capital and labor market dynamics. The latter, in turn, affects the orientation of monetary and fiscal policy. For instance, financing frictions can influence the response of the economy to money shocks (Bernanke, Gertler, and Gilchrist 1999). Clearly, the monetary authorities would wish to condition their actions on this feedback. Similarly, the appropriate position of fiscal policy in the wake of a recessionary shock will depend on how that shock can be amplified by the presence of financing frictions. We see our work as facilitating research into these topics.

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Table 1: Sample Characteristics

	Compustat		Merged panel
	Disclosing firms	Non-disclosing firms	
Number	468	9,309	577
Means:			
Assets (billion \$)	7.18	2.22	4.25
Sales (billion \$)	5.12	1.60	1.01
Employment	20,337	5,616	8,001
Industry makeup (%):			
Durable mfg.	14.3	29.0	36.8
Non-durable mfg.	18.7	22.6	21.8
Transportation	34.4	13.4	7.3
Trade (wholesale & retail)	11.4	9.6	18.9
Services	21.2	25.5	15.2

Calculations are based on a broad sample of firms from Compustat, as well as a smaller random samples with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. This table presents characteristics of firms in Compustat and in our merged panel. With respect to Compustat, we distinguish between firms that disclose Total Staff Expenses (item XLR) and those that do not. We classify a firm as disclosing if it reports staff expenses in each year.

Table 2: Employment in Compustat and the merged panel

	Dependent variable: Employment in Compustat			
Employment in	0.875	0.935	0.513	0.68
merged panel	(0.026)	(0.020)	(0.076)	(0.064)
Constant	1.61	0.947	0	0
	(0.208)	(0.158)		
R^2	0.820	0.900	0.300	0.394
No. of obs.	2,960	2,105	2,960	2,105
Sample	Full	Domestic	Full	Domestic
Fixed Effects	No	No	Yes	Yes

Calculations are based on a broad sample of firms from Compustat, as well as a smaller random samples with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. This table reports the linear projection of log Compustat employment on log employment in our merged panel. In all cases, standard errors are clustered at the firm level.

Table 3: Average Labor Earnings by Size and Leverage

Panel A: Log earnings by terciles of leverage (middle normalized =0)		
Bottom tercile	Middle tercile	Top tercile
0.089	0	-0.026

Panel B: Log earnings by terciles of size (assets)		
Bottom tercile	Middle tercile	Top tercile
0.065	0	0.15

Panel C: Log earnings by terciles of size (employees)		
Bottom tercile	Middle tercile	Top tercile
0.009	0	-0.043

Panel C: Log earnings by size and leverage		
	Assets < median	Assets > median
Leverage < median	-0.054	Normalized = 0
Leverage > median	0.003	-0.076

Calculations are based on a sample of firms from Compustat, with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. This table shows average earnings according to size and leverage, where we define size both as employment and as book assets. In each panel, one category is normalized to zero, and average earnings in the other categories are expressed as a log difference relative to the normalized category.

Table 4: Dynamics of labor earnings in merged panel

	Dependent variable: Labor earnings						
	I	II	III	IV	V	VI	VII
Lag capital	0.105	0.102	0.106	0.105	0.105	0.063	0.097
	(0.014)	(0.016)	(0.014)	(0.014)	(0.014)	(0.012)	(0.022)
Lag employment	−0.105	−0.063	−0.104	−0.105	−0.105	−0.086	−0.111
	(0.050)	(0.082)	(0.050)	(0.050)	(0.050)	(0.051)	(0.054)
Lag leverage	−0.138	−0.149	−0.203	−0.215	−0.054	−0.121	−0.103
	(0.034)	(0.043)	(0.054)	(0.068)	(0.054)	(0.032)	(0.037)
Sales	0.051	0.039	0.051	0.050	0.059	0.025	0.056
	(0.018)	(0.025)	(0.018)	(0.018)	(0.017)	(0.018)	(0.023)
Lag leverage × 1(goods sector)			0.090				
			(0.059)				
Lag leverage × 1(size $<$ median)				0.122			
				(0.075)			
Lag leverage × Sales					−0.021		
					(0.012)		
R^2	0.0929	0.0693	0.0935	0.0943	0.0941	0.151	0.166
Obs.	13306	9566	13306	13306	13306	13306	3041
Sample	Full	Domestic	Full	Full	Full	Full	Full
Time effects	No	No	No	No	No	Yes	Yes
Frequency	Qtly.	Qtly.	Qtly.	Qtly.	Qtly.	Qtly.	Annual

Calculations are based on a sample of firms from Compustat, with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. Estimation is done with OLS. The dependent variable is log labor earnings. The independent variables are once-lagged log capital, once-lagged log employment, once-lagged leverage (net debt divided by assets), and log sales. Column I uses the full quarterly merged panel sales. Column II restricts the sample to domestically oriented firms (see text for definition). Columns III-V add regressors. The indicator 1(goods sector) equals 1 if the firm is classified in a goods-producing industry and zero otherwise. The indicator 1(size $<$ median) equals 1 if the firm's average assets over our sample is less than the median. Dummy variables for each quarter are added in Column VI. Column VII uses annual data, that is, end-of-fiscal-year observations. All regressions use firm fixed effects. Standard errors in all cases are clustered at the firm level.

Table 5: Dynamics of employment in merged panel

	Dependent variable: Employment						
	I	II	III	IV	V	VI	VII
Lag capital	−0.001	0.001	−0.001	−0.001	−0.001	0.007	0.009
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.037)
Lag employment	0.819	0.834	0.818	0.819	0.819	0.819	0.463
	(0.029)	(0.034)	(0.029)	(0.029)	(0.029)	(0.029)	(0.050)
Lag leverage	−0.002	0.001	0.044	0.0005	−0.019	0.001	−0.080
	(0.016)	(0.018)	(0.034)	(0.026)	(0.026)	(0.016)	(0.045)
Sales	0.113	0.111	0.113	0.113	0.112	0.112	0.248
	(0.016)	(0.020)	(0.016)	(0.016)	(0.015)	(0.017)	(0.053)
Lag leverage × 1(goods sector)			−0.063				
			(0.037)				
Lag leverage × 1(size $<$ median)				−0.004			
				(0.034)			
Lag leverage × Sales					0.004		
					(0.005)		
R^2	0.754	0.775	0.755	0.755	0.755	0.757	0.37
Obs.	13306	9566	13306	13306	13306	13306	3041
Sample	Full	Domestic	Full	Full	Full	Full	Full
Time effects	No	No	No	No	No	Yes	Yes
Frequency	Qtly.	Qtly.	Qtly.	Qtly.	Qtly.	Qtly.	Annual

Calculations are based on a sample of firms from Compustat, with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. Estimation is done with OLS. The dependent variable is log employment. The independent variables are once-lagged log capital, once-lagged log employment, once-lagged leverage (net debt divided by assets), and log sales. Column I uses the full quarterly merged panel sales. Column II restricts the sample to domestically oriented firms (see text for definition). Columns III-V add regressors. The indicator 1(goods sector) equals 1 if the firm is classified in a goods-producing industry and zero otherwise. The indicator 1(size $<$ median) equals 1 if the firm's average assets over our sample is less than the median. Dummy variables for each quarter are added in Column VI. Column VII uses annual data, that is, end-of-fiscal-year observations. All regressions use firm fixed effects. Standard errors in all cases are clustered at the firm level.

Table 6: Subsample dynamics of labor earnings in merged panel

	Dependent variable: Labor Earnings		
	I	II	III
Lag capital	0.108	0.201	0.104
	(0.030)	(0.119)	(0.016)
Lag employment	−0.156	0.257	−0.122
	(0.038)	(0.117)	(0.040)
Lag leverage	−0.079	0.012	−0.133
	(0.061)	(0.211)	(0.035)
Sales	0.107	−0.013	0.055
	(0.035)	(0.057)	(0.016)
R^2	0.154	0.441	0.095
Obs	2125	36	10845
Sample	Investment Grade	Junk	No Rating
Time Effects	Yes	Yes	Yes
Frequency	Qtly.	Qtly.	Qtly.

Calculations are based on a sample of firms from Compustat, with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. Estimation is done with OLS. The dependent variable is log labor earnings. The independent variables are once-lagged log capital, once-lagged log employment, once-lagged leverage (net debt divided by assets), and log sales. Column I uses the firms from the quarterly merged panel with an investment grade credit rating. Column II restricts the sample to firms with a below investment grade (junk) credit rating. Column III restricts the sample to firms with with no public credit rating.All regressions use firm fixed effects. Standard errors in all cases are clustered at the firm level.

Table 7: Subsample dynamics of employment in merged panel

	Dependent variable: Employment		
	I	II	III
Lag capital	0.000	−0.018	0.000
	(0.010)	(0.040)	(0.008)
Lag employment	0.811	1.017	0.813
	(0.041)	(0.083)	(0.031)
Lag leverage	−0.029	−0.010	0.005
	(0.020)	(0.073)	(0.018)
Sales	0.106	0.015	0.118
	(0.027)	(0.036)	(0.017)
R^2	0.819	0.904	0.742
Obs	2125	36	10845
Sample	Investment Grade	Junk	No Rating
Time Effects	Yes	Yes	Yes
Frequency	Qtly.	Qtly.	Qtly.

Calculations are based on a sample of firms from Compustat, with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. Estimation is done with OLS. The dependent variable is log employment. The independent variables are once-lagged log capital, once-lagged log employment, once-lagged leverage (net debt divided by assets), and log sales. Column I uses the firms from the quarterly merged panel with an investment grade credit rating. Column II restricts the sample to firms with a below investment grade (junk) credit rating. Column III restricts the sample to firms with with no public credit rating.All regressions use firm fixed effects. Standard errors in all cases are clustered at the firm level.

Table 8: Dynamics of labor earnings in Compustat and merged panel

	Merged panel	Compustat, 2006-12	Compustat, 1970-12
Lag capital	0.097	−0.003	0.064
	(0.022)	(0.036)	(0.016)
Lag employment	−0.111	0.033	−0.109
	(0.054)	(0.048)	(0.024)
Lag leverage	−0.103	−0.019	0.015
	(0.037)	(0.073)	(0.030)
Sales	0.056	0.022	0.087
	(0.023)	(0.031)	(0.023)
R^2	0.166	0.082	0.667
No. of obs.	3041	2851	15986
Year effects	YES	YES	YES

Calculations are based on a broad sample of firms from Compustat, as well as a smaller random samples with labor earnings and employment data from the Bureau of Labor Statistics' Quarterly Census of Employment and Wages. The sample period is first quarter 2006 to fourth quarter 2012. This table presents regression results using annual data. The first column, "Merged panel" uses end-of-fiscal-year observations from our quarterly panel. This is the same result show in Column VII of Table 5. The other two columns here show results using two different sample periods of Compustat data on "total staff expenses" (XLR).

Table 9: Simulated Moments Estimation

Panel A. Moments

	Actual Moments	Simulated Moments	T-statistics
Mean investment	0.024	0.027	-1.074
Mean net debt	0.079	0.093	-1.879
Mean operating income	0.035	0.026	2.160
Income/wages	0.908	0.725	1.118
Standard deviation investment	0.017	0.018	-0.528
Standard deviation employment growth	0.060	0.023	2.161
Standard deviation leverage	0.102	0.026	2.203
Covariance of investment and net debt ($\times$100)	-0.009	-0.002	-1.693
Covariance of employment growth and net debt ($\times$100)	-0.010	-0.008	-0.597
Covariance of investment and employment Growth ($\times$100)	0.004	-0.014	0.978
Wage elatisticity to sales	0.040	0.040	0.008
Standard deviation change in log sales	0.027	0.005	3.394
Serial correlation of log sales	0.601	0.798	-1.346
Serial correlation of leverage	0.786	0.868	-1.193

Panel B. Parameters

λ_0	λ_1	α	β	ρ	σ	δ	c_k	c_n	ξ	ψ
0.0011	0.0446	0.377	0.510	0.684	0.252	0.106	0.854	0.159	0.222	0.320
(0.0002)	(0.0018)	(0.044)	(0.015)	(0.015)	(0.071)	(0.002)	(0.071)	(0.232)	(0.181)	(0.010)

Panel A reports value of moments in the LDE-Compustat stample of 577 firms and in our simulated sample. Panel B reports the estimates of the 11 parameters: α and β are the returns to scale with respect to capital and labor, respectively; δ is the capital depreciation rate; ρ is the persistence of productivity; σ is the standard deviation of the innovation to productivity; ξ is the bankruptcy cost (as a share of a firm's capital stock; λ_0 and λ_1 are the fixed and linear costs of equity issuance; c^k is the resale price of capital outside bankruptcy, and c^+ is the per capita hiring cost. All of the parameters except for λ_0 and λ_1 are estimated via simulated method of moments. λ_0 and λ_1 are estimated via linear regressions of issuance fees on issuance proceeds.

Table 10: Counterfactual responses of factor demands and wages to financing costs

	Response to 50 bp $\uparrow$ in r	
	Data	Model
Employment	-5.5%	-6.0%
Labor earnings	na	-7.2%
Capital	na	-2.8%

This table reports the the response of employment to an increase in financing costs from Chodorow-Reich (2014). It also reports model generated responses of employment, labor earnings, and capital.

Figure 1: Loan Contract

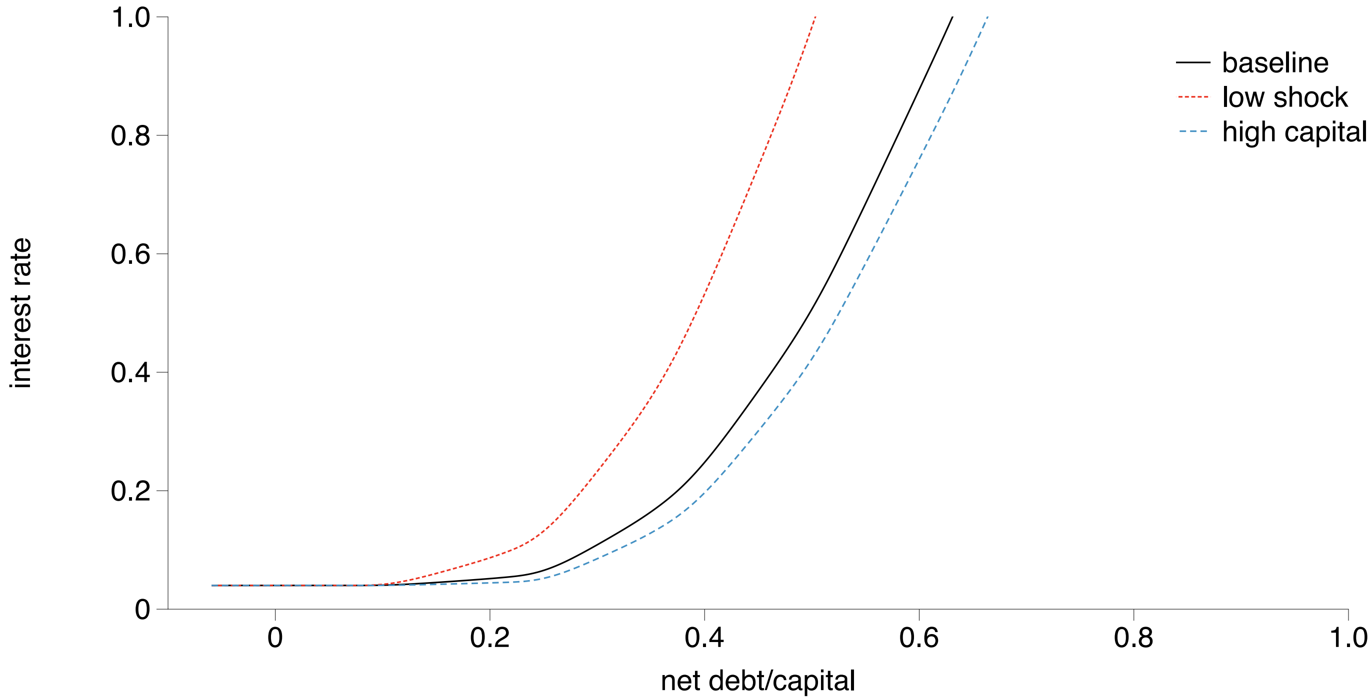


Figure 1 plots the contractual rate of interest in loan agreements for different values of labor, capital, and productivity. The debt levels that run along the horizontal axis are all normalized by the mean capital stock.

Figure 2: Wage Bargain

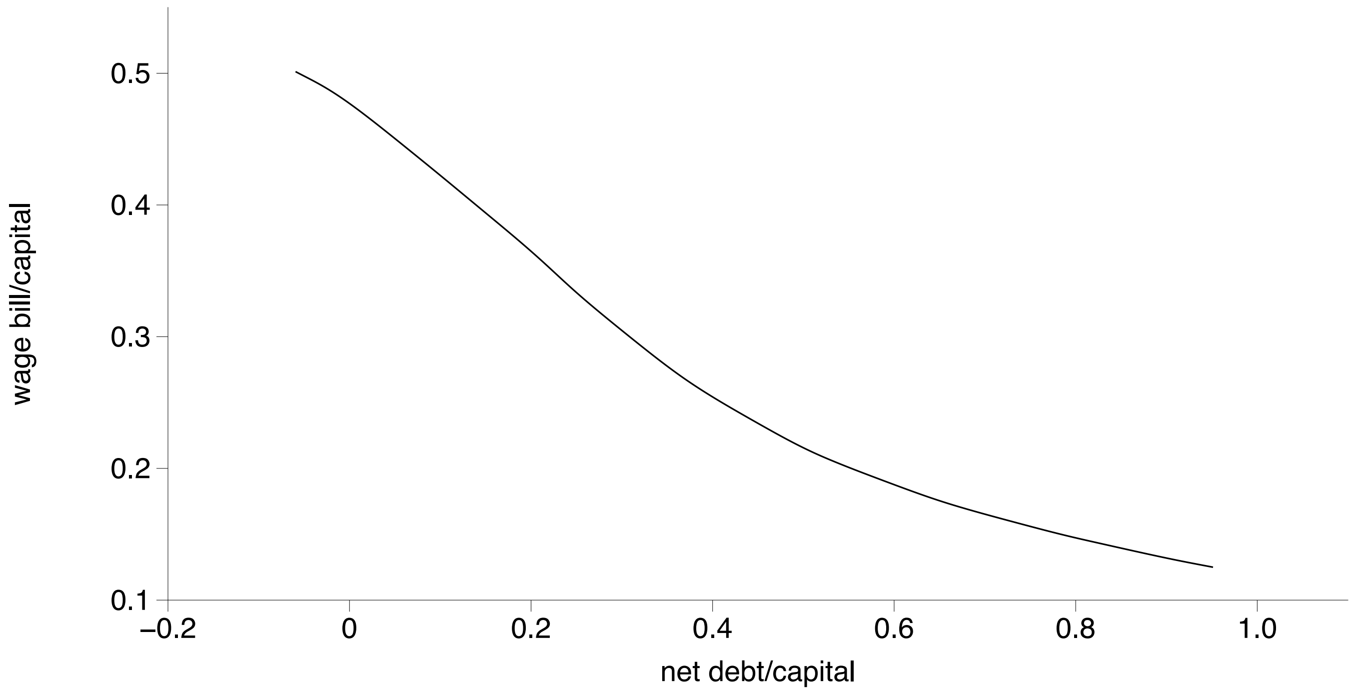
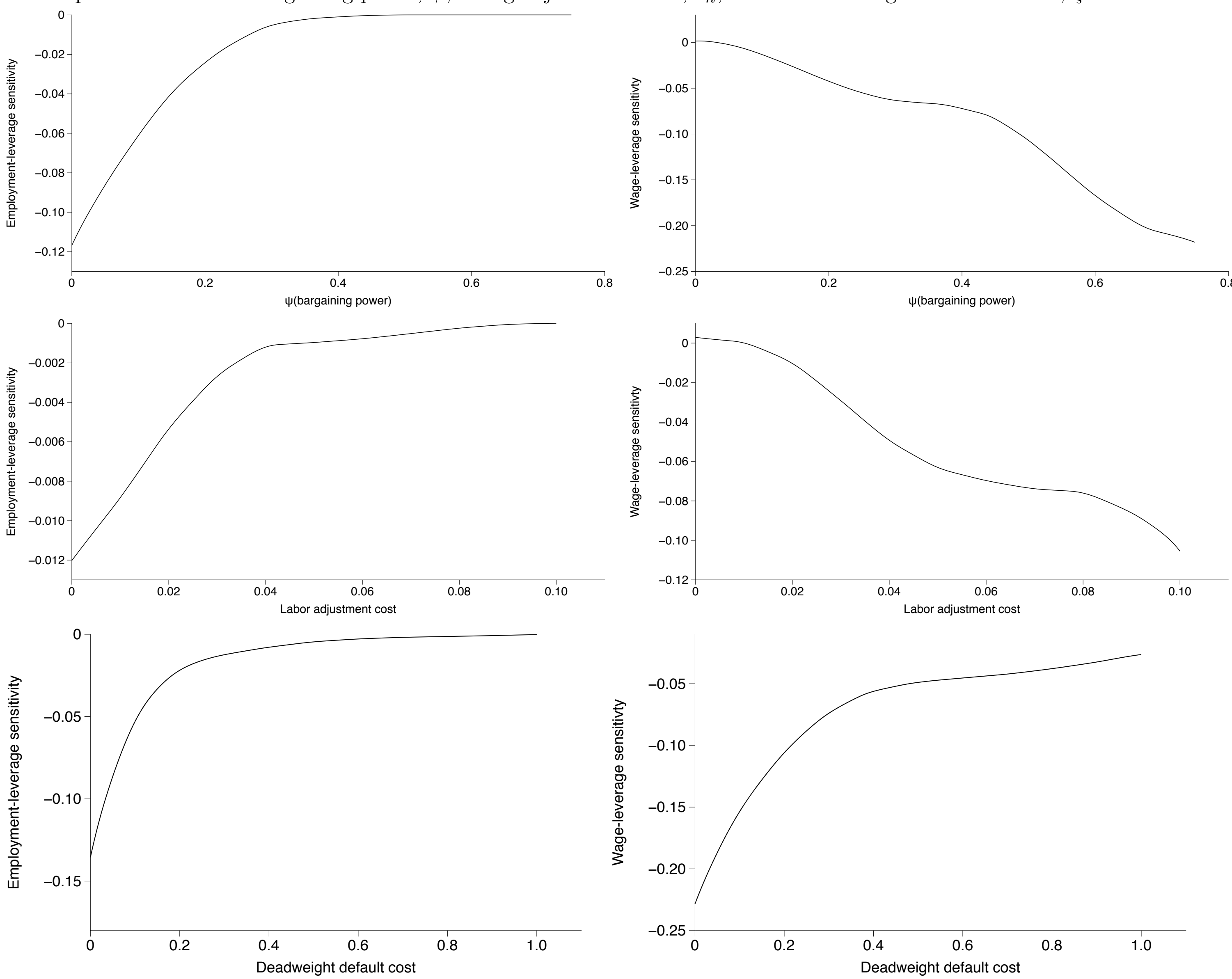


Figure 2 plots the wage bill given common values (in our simulations) of labor, capital, and productivity. The wage bill is normalized by its value over the risk-free region of (small) debt levels.

Figure 3: Sensitivity of Labor Earnings and Employment to Leverage

Figure 3 shows how the elasticity of employment and leverage each change with respect to three model parameters: labor bargaining power, ψ, hiring adjustment costs, c_n, and the deadweight cost of default, ξ.



Appendix A

In this appendix, we provide some additional details regarding how the merged panel is constructed. Ideally, we would execute this merge for all Compustat parent firms. However, because corporations in Compustat can have hundreds of establishments and Infogroup charges by the establishment, this strategy is too costly. In light of this issue, we have constructed our sample in the following way.

First, we draw a random sample of 1000 firms from Compustat. The universe from which the sample is drawn consists of firms that operated at some point in time since 2000. Some of these firms, however, have workforces based largely outside the U.S. This detail complicates our analysis because we observe the firm's global balance sheet in Compustat but only its U.S. employment and wage bill in LDE. Hence, we discard firms whose workforces are substantially based overseas. More specifically, we investigate firms with annual sales greater than \$10 billion because they are the firms most likely to have a large international presence. We then discard those whose U.S. employment makes up less than three-quarters of their total workforce. This criterion eliminates roughly 200 firms.

Second, we deliver our list of parents to Infogroup and request that it pull records on each parent's establishments. To this end, we make the identifying assumption that if two establishments *within* the same state are operated by the same parent, they use the same EIN. This assumption is useful because it implies that for each parent in a given year, we can conserve on costs by requesting information from Infogroup on *one establishment* per state per parent. We chose to ask for the name and address of the oldest establishment. Therefore, using our sample selection, the year-t cross section from Infogroup records the names and addresses of the oldest-operating establishment of each parent in each state in which the parent is active in that year. Note that if we match the oldest establishment to a record in the LDE, then (under our identifying assumption) we can discover the unique EIN that the parent uses in the state. This procedure allows us to pinpoint the remaining establishments in the LDE operating under that parent in the state. Thus, even though the high cost of ReferenceUSA data can be constraining, we can still merge ReferenceUSA to the

LDE.

Not surprisingly, we have identified some violations of this identifying assumption, in which different EINs are used within a single state. Because we under-count the parents' establishments in these cases, we typically find that our estimate of the parent's employment is substantially less than the annual Compustat figure. We follow up in these scenarios by doing internet searches to track down the names and addresses of additional establishments operated by the parent in each state. These searches produce (in the LDE) the EINs we are missing. We again "hard-code" an allowance for this type of situation into the matching code.

We have requested two annual cross sections from Infogroup, one from 2006 and another from 2012. We match each to the LDE. The use of the 2006 cross section means that, if a firm operated in a state in 2006 but exited by 2012, we will still be able to identify the firm's establishments in that state in the LDE data. However, if the firm enters and exits a state between 2007 and 2011, we will miss it, and thus under-count employment for those years.

Infogroup retrieves comprehensive data for 808 of the 1000 parents on our list. We, in turn, have been able to match 577 of these parents to the LDE, so our panel consists of these firms spanning the period 2006-2012.

Merging ReferenceUSA to LDE

As a first step, we standardize names and addresses. For instance, "Corporation", "Corp.", and "Corp" are all set to the latter value. The conventions for standardization follow practices at the Census Bureau.

Next, the character-matching algorithm identifies establishments in the LDE that inhabit the same state and exhibit a "similar" name to the corresponding establishment in ReferenceUSA. Our principal criterion for "similar" is that the first three-quarters of the characters in the ReferenceUSA and LDE names agree identically, although we relax this criterion if establishments match exactly on zip code. We stress agreement on the initial characters of each name because keypunch errors tend to increase as strings advance from left to right (Winkler 2006). If we fail to match several of a parent's ReferenceUSA establishments, we manually examine how these establishments' names are recorded in the LDE (by, for instance, looking up the name in LDE corresponding to the address in ReferenceUSA). One can usually identify a pattern to the discrepancy, in that the LDE consistently reports a variant of the ReferenceUSA name. We then make an allowance for these variations in the matching code.

Missing data in LDE

One remaining challenge is that a seven states— Florida, Massachusetts, Michigan, Mississippi, New Hampshire, New York, and Pennsylvania—do not make their micro data available through the BLS. Thus, in all, we have data for 43 states and territories, including Delaware and Nevada, where most U.S. corporations are incorporated. For this reason, we have been using both LDE and Compustat data to estimate employment and the wage bill. In particular, if we are missing states at random, then LDE provides a consistent estimate of the average wage *rate* and quarterly employment *growth*. We can combine this information with end-of-fiscal-year estimates of the level of employment in Compustat to estimate firm-wide wages and employment in each quarter.

Changes in ownership

A second challenge has to do with changes in ownership. Suppose a parent divests of several establishments between 2006 and 2012. If those establishments adopt new EINs, we will, appropriately, exclude them when aggregating across the parent's EINs. However, we have noticed that if the establishments operated as a wholly own subsidiary and if the *entire* subsidiary is divested, then the plants may retain their original EINs. This situation is especially likely if the subsidiary—and its establishments—never shared the same EIN as its original parent's headquarters, and if it continues intact under the new parent. In these cases, we would (wrongly) continue to assign these establishments' employment to the original parent, since they report the same EIN as in 2006. To address this concern, we try to identify likely changes in ownership based on "jumps" in Compustat's data on assets. Using internet searches, we then determine if a change in ownership did occur and make an allowance for this in the matching code.

Data definitions

Our Compustat variables are defined as follows. Investment is given by ((CAPXY - SPPEY) / lag(PPENTQ). Because CAPXY and SPPEY are reported cumulatively over the year, we first difference to obtain the actual quarterly expenditures. Net debt is defined as book assets minus book equity minus cash: ATQ - SEQQ + TXDITCQ + PSTKQ - CHEQ. Leverage is book debt scaled by ATQ. Operating income is IOBDPQ.

In the LDE, monthly employment at the establishment is defined as employment in the pay period including the 12th of the month. We average monthly employment over each calendar quarter to create the quarterly panel. The monthly wage bill is total wages paid by the establishment during the month. We calculate the average wage by simply dividing the wage bill by employment and, again, take the quarterly average. For both the LDE and Compustat variables, we winsorize the top and bottom 2.5% of observations.

Appendix B

Preliminaries

The wage bargain sets the wage rate to split the match surplus between the firm and worker. Let $\mathcal{J}$ denote the firm's surplus and $\mathcal{W}$ the worker's surplus. The wage then solves

$$\mathcal{W} = \varphi\left(\mathcal{J} + \mathcal{W}\right), \tag{10}$$

where $\varphi \in (0, 1)$ is the worker's bargaining power. In what follows, we first assess $\mathcal{J}$, then turn to the worker's problem.

Throughout, we make use of an approximation to facilitate the analysis. We assume that states of nature where dividends are non-positive are sufficiently unlikely to be realized that they may be neglected in the calculation of the continuation value. As noted in the main text, this is a good quantitative approximation because these states are rare unconditionally and, if one does occur, it is unlikely to be repeated soon. As a result, the evaluation of the firm's future marginal value of labor assumes that its choice of future debt, b', is unconstrained.

The firm's problem

Since a vacant job yields zero return to the firm, the firm's surplus is the marginal value of labor. For given employment n, capital stock k, and a choice of debt b, this is

$$\mathcal{J}(b,k,n,z) = -\frac{\partial W(b,k,n,z)}{\partial n} + \beta \frac{\partial}{\partial n} \mathrm{E}\left[\Pi\left(\omega,k,n,z'\right)\right], \tag{11}$$

in which the arguments of the wage bill, W, preview the solution below.[10] The first term in (11) represents the effect of a new hire on the wage bill. Note that, for given b and k, a perturbation to n affects dividends solely via W. (Such a perturbation does not imply a marginal adjustment cost, because these costs are sunk by the time the surplus is divided.) The second term in (11) expresses the future marginal value of labor. To evaluate this, we must explore the firm's labor demand decision in greater detail.

Given the form of factor adjustment costs, we assume the optimal employment policy consists of three regimes. For a low range of productivity realizations, the firm fires; for a high range of productivity draws, the firm hires; and for an intermediate range, the firm does not adjust employment. In case the firm fires, we conjecture that capital demand is non-increasing, that is, the firm either opts not to undertake gross investment or chooses to disinvest. This is in fact the optimal policy under frictionless credit markets if the cost of adjusting capital is sufficiently large relative to the cost of adjusting labor (Dixit, 1997; Eberly and van Mieghem, 1997). In the same spirit, we conjecture capital demand is non-decreasing if the firm hires, and that gross investment is zero if the firm chooses not to adjust employment. We then verify in our simulations that this policy obtains.

[10] To emphasize that the derivative of $\mathrm{E}[\Pi(\omega,k,n,z')]$ reflects the direct effect of n as well as its effect via ω, we use $\mathrm{d}n$ in place of the conventional partial differentiation notation.

This optimal labor demand policy implies that, by Leibniz's rule, the marginal value of labor is

$$\begin{aligned}
\frac{\partial}{\partial n}\mathrm{E}\left[\Pi\left(\omega,k,n,z'\right)\right] &= \int_{\text{Firing}}\frac{\partial}{\partial n}\Pi^{f}\left(\omega,k,n,z'\right)\partial G\left(z'|z\right) \\
&+ \int_{\text{Inaction}}\frac{\partial}{\partial n}\Pi^{0}\left(\omega,k,n,z'\right)\partial G\left(z'|z\right) \\
&+ \int_{\text{Hiring}}\frac{\partial}{\partial n}\Pi^{h}\left(\omega,k,n,z'\right)\partial G\left(z'|z\right),
\end{aligned} \tag{12}$$

where the subscript in a value function, such as Π^f, refers to the labor demand regime. For example, "f" is for firing. Note that could further decompose the value of firing (hiring) into two regimes, one where the firm does zero gross investment and one where z' is low (high) enough to trigger disinvestment (positive investment). However, this decomposition is unnecessary here, since under our conjecture, the Envelope theorem applies to the labor demand decision in both regimes.[11]

To evaluate this continuation value, we consider each of the three regimes in turn.[12]

Firing. Consider a firm that is calculating the marginal (present) value of this period's labor n in the event that it fires next period ($n' < n$). The value of the firm next period is given by,

$$\Pi^{f}\left(\omega,k,n,z'\right) = \max_{b',k',n'}\left\{\begin{array}{c}\left(\omega+b'-W\left(b',k',n',z'\right)-R\left(k',k\right)\right)\\ +\beta\int\Pi\left(\omega',k',n',z''\right)\partial G\left(z''|z'\right)\end{array}\right\}, \tag{13}$$

where future cash on hand ω' is

$$\omega' = z''f\left(k',n'\right)-\left(1+r'\right)b'. \tag{14}$$

Note that, if the firm defaults at the beginning of the period, the firm's output and fixed assets are transferred to the lender such that ω is reset to zero. Hence, (13) holds but with

[11]Since the cost of adjusting capital is linear in $\Delta k' \equiv k'-k$, the Envelope theorem also implies that Π^f is independent k in periods of capital adjustment. Hence, in these states, Π^f is a function of only two arguments (ω, z').

[12]Non-adjustment is optimal in some states of nature because the marginal cost of adjusting is discretely higher than zero. Therefore, for small fluctuations in productivity, the marginal benefit of adjusting does not exceed marginal cost. In the absence of financial frictions, it can be shown that this structure of adjustment frictions implies an optimal employment policy of this form. See xxxxxxxxxElsby and Michaels (2013).

$\omega = 0$.

Equation (14) indicates that ω' does not directly depend on n. It follows that $\Pi^f(\omega, k, n, z') = \Pi^f(\omega, k, z')$, that is, n comes in only indirectly via cash on hand, ω. Therefore, by the Envelope theorem, a firm this period calculates the future marginal value of labor in this regime to be

$$\frac{\partial}{\partial n}\Pi^f\left(\omega, k, z'\right) = \Pi_1^f\left(\omega, k, z'\right)\frac{\partial\omega}{\partial n} = \frac{\partial\omega}{\partial n} \tag{15}$$

This says that, since the firm will re-optimize its labor demand next period ($n' < n$), the only effect of today's labor n on its future present value is channeled through its effect on start-of-next period cash on hand. Clearly, if the firm defaults, then $\partial\omega/\partial n = 0$.

Hiring. A hiring firm's present value is

$$\Pi^h\left(\omega, k, n, z'\right) = \max_{b',k',n'}\left\{\begin{array}{c}\left(\omega + b' - W\left(b', k', n', z'\right) - c^n\Delta n' - R\left(k', k\right)\right) \\ +\beta\int\Pi\left(\omega', k', n', z''\right)\partial G\left(z''|z'\right)\end{array}\right\}, \tag{16}$$

where $\Delta n' \equiv n' - n$. Again, if the firm defaults in this state of nature, (16) obtains with $\omega = 0$. By the Envelope Theorem, the marginal value of labor is then

$$\frac{\partial}{\partial n}\Pi^h\left(\omega, k, n, z'\right) = \Pi_1^h\left(\omega, k, n, z'\right)\frac{\partial\omega}{\partial n} + \Pi_2^h\left(\omega, n, z'\right) = \left(\frac{\partial\omega}{\partial n} + c^n\right), \tag{17}$$

with $\partial\omega/\partial n = 0$ in the case of default.

Inaction. Next, consider a firm that does not adjust next period, that is, $\Delta n' = 0$. (Recall that, under our conjecture, $\Delta k' = 0$, too.) Its present value is

$$\Pi^0\left(\omega, k, n, z'\right) = \max_{b'}\left\{\left(\omega + b' - W\left(b', k, n, z'\right)\right) + \beta\int\Pi\left(\omega', k, n, z''\right)\partial G\right\}.$$

By the Envelope theorem (as applied to b'), the firm this period calculates the future marginal value of this period's labor to be

$$\begin{aligned}\frac{\partial}{\partial n}\Pi^0\left(\omega,k,n,z'\right) &= \left(\frac{\partial\omega}{\partial n}-\frac{\partial W(b',k,n,z')}{\partial n}\right)+\beta\frac{\partial}{\partial n}\int\Pi\left(\omega',k,n,z''\right)\partial G \\ &= \frac{\partial\omega}{\partial n}+\mathcal{J}\left(b',k,n,z'\right).\end{aligned} \tag{18}$$

Summing up. Piecing together (15), (17), and (18) and combining with (11) yields

$$\begin{aligned}\mathcal{J}\left(b,k,n,z\right) = -\frac{\partial W(b,k,n,z)}{\partial n} \\ +\beta\left\{\begin{array}{c}\int_{\text{Non-default}}\frac{\partial\omega}{\partial n}\partial G\left(z'|z\right) \\ +c^n\int_{\text{Hiring}}\partial G\left(z'|z\right)+\int_{\text{Inaction}}\mathcal{J}\left(b',k,n,z'\right)\partial G\left(z'|z\right)\end{array}\right\}.\end{aligned} \tag{19}$$

Note that, as anticipated by the discussion above, the partial effect of n on cash-on-hand ω, $\partial\omega/\partial n$, is weighted by the probability of survival.

Surplus sharing

The firm and worker split the match surplus according to (10). The worker's surplus is given by

$$\mathcal{W}\left(b,k,n,z\right)=w\left(b,k,n,z\right)-\mu+\mathrm{E}\left[\left(1-s'\right)\cdot\mathcal{W}\left(b',k',n',z'\right)\right], \tag{20}$$

where $w\left(b,k,n,z\right)\equiv W\left(b,k,n,z\right)/n$ is the wage per worker; μ is the flow return to non-employment; and s' is the probability of separation from the firm next period. The surplus-sharing arrangement (10) sets $\mathcal{W}\left(b',k',n',z'\right)=\frac{\varphi}{1-\varphi}\mathcal{J}\left(b',k',n',z'\right)$. Since b' and n' are chosen optimally, the FOC of a firing firm implies that it fires until the marginal value of a worker is zero. That is, differentiating (13) w.r.t. n shows that

$$\Delta n'<0:\mathcal{J}\left(b',k',n',z'\right)=0. \tag{21}$$

By the same logic, a hiring firm expands employment until the marginal value of labor is just offset by the hiring cost, c^{+}. Therefore,

$$\Delta n'>0:\mathcal{J}\left(b',k',n',z'\right)=c^n. \tag{22}$$

If the firm does not adjust n, then $\mathcal{J}(b', k', n', z') = \mathcal{J}(b', k, n, z')$.

Combining these expressions, using the mapping from $\mathcal{W}(b', k', n', z')$ to $\mathcal{J}(b', k', n', z')$, and substituting into (20) yields

$$\begin{gathered}\mathcal{W}(b, k, n, z) = \tfrac{W(b,k,n,z)}{n} - \mu \\ +\beta \tfrac{\varphi}{1-\varphi}\left\{\textstyle\int_{\text{Inaction}} \mathcal{J}(b', k, n, z')\,\partial G + \int_{\text{Hiring}} c^n \partial G\right\}.\end{gathered} \tag{23}$$

Next, we substitute (19) and (23) into the surplus-sharing rule (10). After canceling terms and noting that $\frac{\partial W(b,k,n,z)}{\partial n} = w(b, k, n, z) + \frac{\partial w(b,k,n,z)}{\partial n} n$, we have

$$w(b, k, n, z) = \varphi\left(\beta \int_{\text{Non-default}} \frac{\partial \omega}{\partial n} \partial G(z'|z) - \frac{\partial w(b, k, n, z)}{\partial n} n\right) + (1-\varphi)\mu. \tag{24}$$

Equivalently, we can recall that default is a single crossing condition, namely, the firm defaults if productivity, z', is less than a threshold, $\zeta(b, k, n, z)$. Then (24) becomes

$$w(b, k, n, z) = \varphi\left(\beta \int_{\zeta(b,k,n,z)} \frac{\partial \omega}{\partial n} \partial G(z'|z) - \frac{\partial w(b, k, n, z)}{\partial n} n\right) + (1-\varphi)\mu.$$

Remark 1 : Our neglect of future zero-dividend states should not be taken to mean that the possibility of a zero-dividend state, conditional on a labor demand policy, is unimportant to the firm's decision. Rather, the key observation is that the continuation values in the surplus-sharing rule reflect the firm's *optimal* response to this possibility. In simulations of the model, this best response appears to reduce the probability that a zero-dividend state is realized to a virtually negligible level. As a result, our solution to the wage represents a very good approximation.

Remark 2 : Equation (11) is valid in and out of a zero-dividend state, that is, the solution (24) obtains in a zero dividend state as long as that state recurs so infrequently as to be negligible. To see why, note that debt is "sunk" by the time the firm and its workers implement (10). Suppose, in particular, that debt and factor demands have been chosen under the anticipation of a zero dividend. Now, note that the firm's evaluation of the marginal surplus (11) implicitly takes account of how the departure of a worker, taking as given the participation of the remaining workers, would yield a lower wage bill (since $W(b,k,n,z)$, is increasing in n). This would relax rather than tighten the dividend constraint. As a result, the marginal reduction in the wage bill is passed through as a marginally higher dividend, just as if the dividend was anticipated to be positive.