Production Technology and Debt Maturity Structure

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Abstract

Does production technology affect a firm's debt maturity choice? To address this question, we examine how the factor demands for labor and fixed capital change optimal debt maturity choices. Without payback guarantees of principles and interests, creditors seek collaterals for their debt contracts. Yet, they have very restricted ways to secure the fund used for wage payments. Hence, a firm with substantial wage payments relies more significantly on shorter term debt financing, which is relatively free from collateral requirements. Because production technology determines this factor demand for labor and fixed capital, a firm's technology plays a critical role in deciding optimal debt maturity policy. Our theory highlights this factor demand channel and predicts a shorter debt maturity structure for labor intensive firms. Consistent with our predictions, we find that labor intensive U.S. manufacturing firms show shorter debt maturity structures and exercise active short-term debt policies.

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1 Introduction

Does real production technology affect the maturity choice of firm? We address this question by examining how the factor demands for two major production inputs, labor and fixed capital, influence optimal debt maturity structures. Because a firm's technology plays the central role in shaping such factor demands, our arguments highlight the importance of production technology in debt maturity choices. Existing literature has paid little attention to the role of production technology, even though a number of empirical studies have suggested the importance of this factor demand channel, at least with respect to fixed capital acquisition (e.g. Fan, Titman, and Twite 2012).

To be specific, this paper theoretically argues and empirically verifies a shorter debt maturity structure for labor intensive firms. The difference in pledgeability between the purchase of labor and fixed capital lies at the core of our analysis. Creditors can easily secure physical assets as collateral in case of defaults, which allows a collateralized long-term debt contract. In contrast, the fund used for wage payments is hardly pledgeable by creditors; a firm has to rely substantially on shorter term debt financing for wage payments, which is relatively free from collateral requirements. Hence, a labor intensive firm with substantial wage payments tends to show a shorter debt maturity structure.

To examine how production technology changes optimal debt maturity policies, we firstly develop a two-period corporate model incorporating the Cobb-Douglas production technology, the time to build nature of production, the option of strategic default, and the possibility of financial market freeze. The time to build nature in production requires advanced wage payments for employees. The representative firm decides whether to use one-period debt, two-period debt, and its own equity to purchase labor and fixed capital. The cost of equity is set larger than that of debt to reflect tax benefits from interest payments. To avoid the possibility of strategic default, creditors lend their money if their debt contract is collateralized or if the firm's continuation value is greater than its default value. Creditors halt debt rollovers as well as new debt issuance in the state of financial market freeze.

Our model shows a shorter debt maturity structure for labor intensive firms, measured by the sales elasticity of labor input. While a two-period debt contract is always the best way to reduce the firm's exposure to financial market freeze, the possibility of strategic default limits such long-term debt issuance for wage payments. Yet, creditors still agree with one-period debt contract for financing wage payments as far as the firm's continuation value is greater than its default value. The representative firm in our model optimally uses an uncollateralized one-period debt contract for initial wage payments and a collateralized two-period debt contract for capital acquisition. Accordingly, a labor intensive firm with more significant wage payments tend to show a higher one-period to two-period debt ratio.

This result allows us to develop novel empirical predictions on the relationship between production technology and debt maturity structures. The Cobb-Douglas technology in our model implies a one-to-one relationship between a firm's labor intensity and its wage to fixed capital ratio. Thus, our model empirically predicts that a labor intensive firm, in terms of wage to fixed capital ratio, tends to show a shorter debt maturity structure. Of course, this prediction can be naturally extended to an industry level analysis as far as the wage to fixed capital ratios varies significantly across industries.

To analyze our theoretical predictions, we employ the sample of listed U.S. manufacturing firms from 1980 and 2013. Because the majority of publicly listed firms in the U.S. market do not report their wage payments and material costs separately, we make a proxy variable for the firm-level wage costs by multiplying the number of employees with the industry average wage rate reported in NIPA Table 6.6. Based on our measure of wage-fixed capital ratio, we conduct firm and industry level analyses on debt maturity policies.

We construct three different measures of debt maturity structure. First, we calculate the proportion of long term debt obligations due less than three years to total long-term debt obligations. This measure is tightly associated with the maturity of long-term debt obligations. A number of extant empirical studies such as Harford, Klasa, and Maxwell (2014) adopt this measure to analyze a firm's debt maturity structure. Second, we employ the ratio of debt in current liability to total debt obligations as another measure of debt maturity. This measure not only captures a firm's overall debt maturity structure, as used in Fan et al. (2012) but also highlights the significance of short-term debt policy. Finally, we use the ratio between note payable to total debt obligations as our last measure of debt maturity. This measure allows us to focus more on a firm's short-term debt policies by excluding the effects of maturing long-term debt obligations.

Our main empirical findings are as follows. Most of all, our firm level analysis shows that labor intensive firms are closely associated with a shorter long-term debt maturity structure. In our cross-sectional models, a higher wage to fixed capital ratio always points to a greater amount of long-term debt obligations due in three years compared to total long-term debt obligations. Our results are robust to the inclusion of fixed effects and other firm characteristic variables. These findings are perfectly in line with our theoretical predictions, which expect a shorter debt maturity for labor intensive firms.

Next, our firm level analysis confirms that labor intensive firms have more significant fraction of short-term debt obligations. In our cross-sectional models, the wage to fixed capital ratio is positively related to the fraction of short-term debt to total debt obligations. This finding remains unchanged whether we use debt in current liability or note payable as our measure of short-term debt obligations. The inclusion of other control variables does not alter our empirical results. This finding verifies an active short-term debt policy as well as a shorter debt maturity structure in labor intensive firms, which is perfectly consistent with our theoretical predictions.

Lastly, we find that a more labor intensive industry has a shorter debt maturity structure. For all three measures of debt maturity structure, our industry estimation results point out a shorter debt maturity structure for the industries with higher wage-fixed capital ratios. The introduction of other industry characteristic variables does not change this relationship. This finding is fully consistent with our model's predictions and strengthens the validity of our firm-level analysis.

This paper contributes to the extant literature in a number of ways. Most of all, we propose a firm's production technology as a critical determinant of debt maturity choices. Prior theories have mainly examined maturity choice in three different contexts: (1) maturity matching (Myers 1977); (2) revealing insider information to public (Diamond 1991); (3) a tool for disciple management (Jensen 1986). Unlike these studies, we highlight that real production procedure plays a pivotal role in deciding optimal debt maturity structures by shaping a firm's factor demands for labor and fixed capital.

Our finding adds a novel dimension to the empirical debt maturity structure literature as well. The existing studies have mainly emphasized the effect of growth options (Johnson 2003), the role of risk profile (Barclay and Smith 1995; Guedes and Opler 1996), or supply side effect (Baker 2009) on debt maturity structures. In contrast, our empirical results suggest the need of wage payments as one of key factors leading to a shorter debt maturity structure, which is robust to the choice of the three different debt maturity measures.

Furthermore, our analysis provides a new economic reason why the value of collateral matters in optimal debt maturity policies. As prior empirical literature established (e.g. Fan et al. 2012), collateral values affect a firm's debt maturity structure substantially. Yet, prior theories largely unexamined how the value of collateral relates to optimal debt maturity choices. Our model clearly shows that the value of collateral changes debt maturity structure via a firm's budgeting problem for the purchase of labor and fixed capital. Our following empirical analysis validates this new economic channel between the value of collateral and debt maturity choices.

Finally, we present a new economic determinant for a firm's short-term debt policy. Despite the quantitative significance of short-term debt obligations in a firm's liabilities, the existing studies paid little attention to the determinant of short-term debt policy. In fact, most studies did not differentiate the determinants of short-term and long-term debt policies (e.g. Hovakimian et al. 2001). Our theory argues the demand of wage payments as a critical reason for short-term debt issuances. This prediction is confirmed in our empirical analysis adopting debt in current liabilities and note payable as a measure of short-term debt obligations.

We provide our theoretical model next section. Section 3 illustrates our empirical strategies and tests the theoretical predictions. Section 4 concludes.

2 Theoretical Model

2.1 Model Set Up

We propose a very simple corporate model to examine the role of production technology in the determination of optimal debt maturity choices.

Timing

There are three dates in our economy, which are denoted as $t = 0, 1$, and 2. We assume that it takes one-period of time to complete production because of the time to build nature in production procedure. Accordingly, the representative firm begins its operation at the first date, $t = 0$ and has two opportunities to generate profits at $t = 1$ and 2. The firm finishes its operation at $t = 2$ and pays out liquidating dividends to shareholders.

Production Technology

The firm needs to purchase physical capital and labor for its production. The firm initially acquires physical capital at $t = 0$. It additionally installs or resales capital stock at $t = 1$. All physical capital is liquidated at $t = 2$. Without loss of generality, we assume no depreciation and no resale discount for physical capital. The price of capital is normalized to one.

The firm has to hire workers for each cycle of production. The wage rate is ω and constant over the time periods. We assume that all workers are wealth-constrained; they do not have any accumulated wealth for consumptions and thus ask advanced payments of wage before the beginning of each production cycle.

The firm's production function takes a standard Cobb-Douglas form in decreasing returns to scale:

$$\begin{aligned} Y_t &= f(K_{t-1}, L_{t-1}) = \theta_t (K_{t-1})^{\alpha} (L_{t-1})^{\beta} \\ \alpha + \beta &< 1 \text{ and } t = 1 \text{ or } 2 \end{aligned}$$

where Y_t is the output of firm at date t. The labor forces, physical capital, and productivity level for the production, Y_t are denoted as L_{t-1}, K_{t-1} and θ_t, respectively. Without loss of generality, θ_t is fixed at θ across the time periods.

Financing and Financial Market Freeze

Debt and equity financing are available to the representative firm. The firm could borrow money from creditors by using two types of debt contract, one-period or two-period debt. The cost of debt is r, which remains the same irrelevant to the maturity of debt contracts. One-period debt requires the payment of principal and interests at its maturity date. Two-period debt additionally involves with an intermediate coupon payment r after one-period of time passes.

One-period and two-period debt contracts differ critically in terms of their exposure to the financial market freeze. All creditors face the same liquidity shock with a (small) probability of p, which freezes the financial market for their lending. This liquidity shock prevents creditors from debt-rollovers as well as new debt issuances. In other words, the firm has to pay all interests and principals for its maturing debt and no longer borrows funds from the creditors, if the liquidity shock occurs. Thus, the use of one-period debt financing increases the firm's exposure to the financial market freeze more significantly compared to the use of two-period debt. This assumption represents the situation of credit market freezes as in the financial crisis of 2008.

The required return for shareholder is ρ, which is greater than the return for creditors. This higher cost of equity represents the existence of interest tax shields and significant flotation costs associated with equity financing. Accordingly, the firm has incentives to use debt financing as much as possible, regardless of debt contract types.

We also allow the option of strategic default. When the firm borrows money from creditors, it makes a promise to repay principals and interests. Yet, shareholders can strategically declare default without paying debt obligations as long as their firm value in default is greater than its continuation value. To avoid potential losses from the strategic default options, creditors may ask the firm to place physical capital as collateral. Or they agree with an uncollateralized debt contract if the firm's continuation value is greater than its default value.

Such collateral requirements critically affect the firm's wage financing policy. Unlike physical capital acquisition, the money used for wage payments are hardly securable by creditors. Therefore, the firm has to rely on uncollateralized one-period debt financing or equity financing for funding wage costs

For simplicity of analysis, we introduce two additional assumptions. First, we presume that the total principals of one-period and two-period collateralized debt cannot be greater than the amount of physical K_t. Second, we do not consider the case that the firm pledges its physical capital for wage payments. Of course, our main findings remain unchanged even if we relax these two conditions.

Without loss of generality, there is no retention of cash. The shareholders receive all remaining profits at $t = 1$ as ordinary dividends rather than save it to the firm's cash account.

2.2 The Value of Equity and Optimal Policies

The possibility of strategic default influences the use of one-period and two-period debt contracts distinctively. Because declaring default is always better off to shareholders at $t = 2$, creditors never agree to two-period debt contracts without collateral at $t = 0$. Similarly, the firm is able to issue one-period debt at $t = 1$ only if it places physical capital as collateral. However, creditors may agree with one-period debt contract at $t = 0$ under two different conditions; they lend their money as one-period debt contract if the firm collateralizes its physical capital or if the firm's continuation value at $t = 1$ is greater than its default value.

We can prove the following propositions based on the assumption that an uncollateralized debt contract for the initial wage costs, wL_0 is available at $t = 0$. In other words, the firm's continuation value at $t = 1$ is greater than its default value even when it issues an uncollateralized debt for all wage payments at $t = 0$. All '*' indicate optimal policies, hereafter.

Proposition 1 *The firm's optimal capital stock at* $t = 0, K_0^*$ *is greater than or equal to the optimal capital stock at* $t = 1, K_1^*$*. The firm uses equity for its wage payments at date*

$t = 1$. *The firm initially issues collateralized two-period debt by the amount of* K_1^* *and issues one-period collateralized debt at* $t = 0$ *by the amount of* $K_0^* - K_1^*$.

Proof. *In Appendix* ■

Proposition 2 *The firm's investment and financing policies are irrelevant to the realization of the liquidity shock to creditors as far as* $K_1^* \leq K_0^*$

Proof. In Appendix ■

The intuitions behind Propositions 1 and 2 are as follows. Most of all, the firm's optimal capital stock at $t = 1$ is smaller than its initial capital stock at $t = 0, (K_1^* \leq K_0^*)$ because the firm has to use more costly equity for wage payments at $t = 1$. This is because the equity financing for wage payments at $t = 1$ increases the overall cost of capital. Next, the firm has to rely on costly equity financing, if the financial market freezes. To avoid such potential losses from financial market freeze, the firm tries to use two-period debt contracts as much as possible. Accordingly, the amount of physical capital that will be used for two cycles of operation, K_1^* is financed by a two-period debt contract. Because all physical capital and labor forces for the second cycle of operation are financed by two-period debt and equity, the realization of financial market freeze does not influence the firm's financing and investment policy.

If the firm could finance initial wage payment wL_0 by the uncollateralized one-period debt, the value of equity finally becomes as follows:

$$
\begin{aligned}
V_0 &= \max_{K_0,K_1,L_0,L_1} \frac{1}{1+\rho}\left[\pi_1 + \frac{1}{(1+\rho)}\pi_2\right] \\
\pi_1 &= \theta K_0^{\alpha} L_0^{\beta} - (1+r)wL_0 - rK_1 - wL_1 \\
\pi_2 &= \theta K_1^{\alpha} L_1^{\beta} - rK_2.
\end{aligned}
$$

Because the firm uses debt financing for initial wage payments, it has to pay the principal and interests for the debt contract as $(1 + r)wL_0$ at $t = 1$. The associated first order conditions are described below:

$$
\begin{aligned}
K_0 &: \alpha\theta K_0^{\alpha-1}L_0^{\beta} = r \\
K_1 &: \alpha\theta K_1^{\alpha-1}L_1^{\beta} = r \\
L_0 &: \theta\beta K_0^{\alpha}L_0^{\beta-1} = w(1+r) \\
L_1 &: \theta\beta K_1^{\alpha}L_1^{\beta-1} = w(1+\rho).
\end{aligned}
$$

The following proposition characterizes the representative firm's optimal debt maturity choices.

Proposition 3 *The firm's one-period to two-period debt ratio is equal to*

$$
\begin{aligned}
\frac{wL_0^*}{K_1^*} + \frac{(K_0^* - K_1^*)}{K_1^*} &= (\frac{wL_0^*}{K_0^*} + 1)\left(\frac{K_0^*}{K_1^*}\right) - 1 \\
&= \left(\frac{r\beta}{(1+r)\alpha} + 1\right)\left(\frac{(1+\rho)}{(1+r)}\right)^{\frac{\beta}{1-\alpha-\beta}} - 1 \qquad (1)
\end{aligned}
$$

which is an increasing function with the labor intensity β.

Proof. In Appendix ■

The one-period to two-period debt ratio consists of two separate components. The first component is related to the significance of wage payments. To avoid the use of more costly equity financing, the firm relies on one-period debt contracts at $t = 0$ based on its continuation value at $t = 1$. The second part is related to maturity matching in capital expenditure. To fund capital stock that is used for only one cycle of operation, the firm tries to use one-period debt contract. As the cost of equity becomes close to the cost of debt, the second part plays a less significant role.

The next proposition describes the condition where one-period debt financing is available for wage payments at $t = 0$.

Proposition 4 *The firm is able to use an uncollateralized one period debt financing for* *initial wage payments if the following condition satisfies:*

$$1-(\alpha+\beta) \geq (1+\rho)(\alpha+\beta)\left(\frac{1+\rho}{1+r}\right)^{\frac{1}{1-\alpha-\beta}}.$$

Proof. *In Appendix* ■

Proposition 4 indicates that the firm continues to operate at $t = 1$ after paying down debt obligations for the initial wage costs, if its profit share to equity holders $(1-\alpha-\beta)$ is large enough. As far as the shareholders earn a great sum of profits from the firm's continued operation, they do not want to declare the firm's default.

2.3 Discussion and Empirical Prediction

Proposition 3 clearly shows that a more labor intensive firm, measured by the sales elasticity of labor, tends to show a higher one-period to two-period debt ratio. Based on the proposition, we can develop novel empirical predictions on the relationship between production technology and debt maturity structures.

The first component in equation (1) demonstrates a close relationship between a firm's labor intensity and its wage to fixed capital ratio. In our model with the Cobb-Douglas production technology, a firm's sales elasticity of labor is directly related to the ratio between wage payments and acquired capital stock. Hence, the proposition suggests the wage to fixed capital ratio as one of the best proxy variables for the unobservable labor intensity parameter.

The one-period to two-period debt ratio in Proposition 3 can be interpreted in a couple of ways. First, a higher one-period to two-period debt ratio could be understood as a shorter long-term debt maturity structure if we consider the relative length of maturities between these two debt contracts. This interpretation of debt maturity is widely used in prior empirical studies such as Harford et al. (2014). They use the ratio of debt in due three years to total debt obligations to measure a firm's debt maturity. As a firm's importance of wage payment enhances, it issues long-term debt with shorter maturities, which are relatively free from collateral requirements.

On the other hand, the one-period debt in our model could be literally considered as short-term debt obligations whose maturity is less than a year. While installed machine or acquired plants could be used for years, a firm has to pay wage quite frequently, for instance, twice a month. To finance such frequent wage payments, a firm may use short-term debt financing more actively. This interpretation is closely associated with the definition of debt maturity structure used in Fan et al. (2012). They use the ratio between a firm's debt in current liabilities to its total debt obligations to measure a firm's overall debt maturity structure. Furthermore, this measure highlights the importance of short-term debt obligations from total debt obligations for a firm's debt maturity.

We may be able to propose a new measure of debt maturity that concerns more about short-term debt policy. A firm's debt in current liability includes both of the note payable and the long-term debt obligations that mature less than a year. We may replace the debt in current liabilities with the amount of note payable in the second measure of debt maturity, to exclude the effect of maturing long-term debt obligations.

The above arguments can be summarized by the following empirical predictions:

- A labor intensive firm, measured by the wage to fixed capital ratio, tends to show a shorter long-term debt maturity structure.
- A labor intensive firm, measured by the wage to fixed capital ratio, tends to show a higher current liability to total debt ratio.
- A labor intensive firm, measured by the wage to fixed capital ratio, tends to show a higher note payable to total debt ratio.

Moreover, we can easily extend our firm level predictions to industry level ones. As far as there are significant variations in the industry level wage-fixed capital ratio, our predictions could directly apply for the relationship between the industry production technology and debt maturity structures.

3 Empirical Analysis

3.1 Data Description

We now test our empirical predictions on the relationship between production technology and debt maturity choices. To do so, we first employ the sample of publicly traded U.S. manufacturing firms (SICs 2000 to 3999) over the 1980 to 2013 period from COMPUSTAT dataset. This choice of time period is a natural one because a majority of firms begin to report their debt maturity items after 1980. We require the sample firm-year observations to provide valid information about their total assets, sales, production costs, fixed capital, cash holdings, and operating income. We also rule out the firm-year observations whose deflated asset value is less than 1 million or deflated fixed capital value is less than 0.5 million in terms of 1997 U.S. dollars. We try to minimize the impact of sample attritions on our estimation results by requiring that the sample firms provide more than five years of valid information. Our final sample consists of 56,187 firm-year observations.

According to our discussion in previous section, the wage-fixed capital ratio plays a pivotal role in representing a firm's production technology, and thus critically affects optimal debt maturity structure. Because only a small fraction of firms report their labor costs, we have to approximate the firm level wage costs to test our empirical predictions. We construct the wage costs for a firm-year observation by multiplying its number of employees with the industry average wage rates reported in NIPA table 6.6. The calculation of industry wage rate is based on two digits of SIC code before 2000 and three digits of NAICS code after 2001 by following the NIPA documentations.

Our definitions of debt maturity structure variables are as follows. We measure a firm's long-term debt maturity by taking the ratio between its long-term debt due in the next three years and total long-term debt obligations. We also use the ratio between a firm's debt in current liabilities and total debt obligation as another measure of debt maturity structure. This variable captures the importance of a firm's short-term debt policy as well as its overall debt maturity structure. To focus more exclusively on short-term debt policy, we introduce the ratio of note payable to total debt obligations as our last measure of debt maturities. Note payable excludes the effect of maturing long-term debt obligations from the debt in current liabilities.

We incorporate a number of control variables for our maturity structure analysis by following the existing empirical studies such as Harford et al. (2014). Firm size is defined as the logarithm of real book value of asset. It controls for the possibility that smaller firms tend to use bank debt with a shorter maturity. Market to book firm value ratio captures the importance of growth option in debt maturity structure, as argued in Myers (1977). I define the average asset maturity of a firm as the book value-weighted maturity of long-term assets and current assets; the maturity of long-term assets is computed as gross property, plant, and equipment divided by depreciation expenses, and the maturity of current assets is calculated as current assets divided by the cost of goods sold. Future year abnormal earnings is the difference between earnings per share in year t + 1 (excluding extraordinary items and discontinued operations and adjusted for any changes in shares outstanding) less earnings per share in year t, divided by the year t share price. A manager with private information about higher future earnings tends to use a shorter term debt financing because a change in firm value has a greater effect on the value of longer-term debt. Book leverage is the ratio between a firm's total long-term debt obligations and book assets. As predicted in Diamond (1991), a firm's liquidity risk increases with leverage ratio, leading to a more significant use of longer term debt for the firms with large debt obligations. Rating dummy is equal to one for the investment grade firms. A higher credit rating firm could borrow money with no significant reliance on collateral. The tangibility measure, defined as the ratio of net property, plant, and equipment to total asset, is the traditional measure of collateral values.

We also construct a set of macroeconomic variables to capture economy-wide effects on debt maturity structures. Term spread, the yield difference between one-year and ten year government bond is included to compare the cost of short-term and long-term debt issuance. Real short-term rate, the real interest rate for one year t-bill is introduced to capture accounting-driven considerations about current interest costs, as in Faulkender (2005). Default spread, the spread between AAA and BAA bonds, tends to be counter cyclical, which also provides important information about the business cyclical movements.

Table 1: Summary Statistics

Variable	Average	Quartile 1	Median	Quartile 3	S.D.
Long Term Debt: Matures in 3 years	0.40	0.12	0.29	0.65	0.34
Current Debt/ Total Debt	0.30	0.06	0.18	0.46	0.31
Note Payable/ Total Debt	0.16	0.00	0.00	0.22	0.28
Wage/Fixed Capital	1.97	0.79	1.41	2.38	1.93
Size	4.97	3.37	4.73	6.40	2.12
Market/Book ratio	1.75	1.03	1.34	1.96	1.25
Future Abnormal Earnings	0.01	-0.04	0.00	0.04	0.23
Asset Maturity	8.55	3.77	6.56	10.94	7.16
Book Leverage	0.21	0.05	0.19	0.32	0.17
Tangibility	0.26	0.14	0.24	0.36	0.16
Return on Asset	0.10	0.06	0.12	0.18	0.15

This table documents summary statistics for debt maturity measures, wage to fixed capital ratio and other firm characteristic variables. The mean, 1st quartile, median, 3rd quartile and the standard deviations are reported from our sample. Size is the logarithm of real book value of asset; Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price. Book leverage is the ratio between total long term debt and book assets. The tangibility measure is the ratio of net property, plant, and equipment to total asset.

3.2 Empirical Results: Firm Level

Table 1 summarizes the variables of interests. The table reports the mean, first quartile, median, third quartile and standard deviations for the variables used in our empirical study. The fraction of long-term debt obligations due in three years is 0.40 on average, which indicates a significantly shorter long-term debt maturity structure in the U.S. manufacturing firm. The ratio between current and total debt obligations is also quite high at 0.30 on average, which points to the importance of current debt obligations in total debt management policy. Even though a median firm does not have the balance of note payable, the mean of note payable to total debt ratio is around 0.16. A group of firms appear to rely widely on notes as their way of debt financing. The average and median of wage-fixed capital ratio is 1.97 and 1.47, which indicates the dominance of wage payments in a firm's budgeting problem. For an average firm, the fund needed for wage payments in almost as twice as its current fixed capital stock. The summary statistics on other variables of interests are in line with those of prior empirical studies.

Long Term Debt Maturity: Due in 3 years

To empirically test our prediction on long-term debt maturities, we estimate cross-sectional regression models for six different specifications. Table 2 reports the coefficients, t-values (in parenthesis) and other statistics from our estimations with robust standard errors. The first model investigates a simple relation between the fraction of long-term debt due in three years out of total long-term debt and the wage-fixed capital ratio. The third model introduces a set of widely used firm characteristic variables similar to Harford et al. (2014). The fourth model additionally includes the tangibility measure, which is a balance sheet measure of collateral values. Our sixth model also controls some macroeconomic conditions by using term spread, default spread and real short rates. The second and fifth models include year fixed effects to capture the time trend of decreasing debt maturity (Harford et al. 2014).

Table 2 clearly points out that labor intensive firms tend to have a shorter long-term debt maturity structure. For all of the six models in Table 2, our wage-fixed capital ratios are positively correlated with the fraction of long-term debt due in three years out of total long-term debt obligations. This relationship is economically significant and robust to the inclusion of the firm and macroeconomic control variables. For example, the coefficient is 0.05 in model (1) and is still 0.019 in model (6) even after controlling for all firm level and macro-economic variables In other words, one standard deviation change in our wage to fixed capital is related to 10-25 % increase in the fraction of long term debt obligations due in 3 years for an average manufacturing firm. All other coefficients on the control variables are in line with previous estimation results such as Harford et al. (2014), and Greenwood et al. (2010).

The estimation results in Table 2 are fully consistent to our model prediction. We theoretically predict a shorter long-term debt maturity structure for labor intensive firms. Thus, the firms with higher wage to fixed capital ratio are predicted to show a significant amount of long-term debt due in three years compared to total debt obligations. The positive coefficients on our wage to fixed capital ratios validate our model predictions on

Table 2: Wage/Fixed Capital and Long-term Debt Maturity

	(1)	(2)	(3)	(4)	(5)	(6)
Wage/FC	0.050***	0.049***	0.029***	0.021***	0.017***	0.019***
	(45.1)	(44.8)	(25.0)	(16.4)	(13.5)	(14.9)
Size			-0.031***	-0.032***	-0.047***	-0.039***
			(-32.6)	(-33.7)	(-46.7)	(-40.5)
M/B Ratio			0.022***	0.020***	0.010***	0.013***
			(13.0)	(12.3)	(6.0)	(7.8)
Abnormal Earnings			0.049***	0.049***	0.031***	0.039***
			(6.5)	(6.6)	(4.3)	(5.3)
Asset Maturity			-0.000	0.003***	0.001*	0.001***
			(-1.3)	(7.9)	(1.8)	(4.2)
Book Leverage			-0.358***	-0.335***	-0.345***	-0.336***
			(-33.7)	(-31.2)	(-33.0)	(-31.8)
Rating Dummy			-0.096***	-0.098***	-0.106***	-0.111***
			(-20.9)	(-21.2)	(-22.6)	(-23.9)
Tangibility				-0.223***	-0.087***	-0.146***
				(-14.2)	(-5.6)	(-9.4)
Term Spread						0.019***
						(12.7)
Default Spread						-0.098***
						(-28.1)
Real Short Rate						-0.014***
						(-20.5)
Intercept	0.311***	0.195***	0.585***	0.640***	0.534***	0.799***
	(132.9)	(32.6)	(74.5)	(72.9)	(53.4)	(77.9)
Year F.E.	No	Yes	No	No	Yes	No
N	41317	41317	38491	38491	38491	38491
adj-R^2	0.060	0.090	0.190	0.194	0.255	0.229

This table describes our model estimation results for the relationship between the wage-fixed ratio and long term debt maturity. The dependent variable is the fraction of long-term debt due in three years. Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price. Book leverage is the ratio between total long term debt and book assets; The tangibility measure is the ratio of net property, plant, and equipment to total asset; Term spread is the yield difference between one-year and ten year government bond; Default spread, the spread between AAA and BAA bonds; Real short term rate, the real interest rate for one year t-bill, The standard errors are robust to heteroskedasticity and the associated t-statistics are reported in parentheses..

long-term debt maturity structures.

This finding argues for the importance of production technology in optimal debt maturity choices. Our model shows that a firm's technology critically affects optimal debt maturity choices by determining the factor demand for labor and fixed capital. We robustly confirm that a higher wage-fixed capital ratio points to a shorter long-term debt maturity structure, which strongly supports a significant role of production technology in optimal debt maturity decisions. Our finding differs markedly from the existing studies of debt maturity choices. This strand of literature has mainly focused on (1) maturity matching (Myers 1977); (2) revealing insider information to public (Diamond 1991) (3) a tool for disciple management (Jensen 1986) in optimal debt maturity policies.

The estimation results also verify an economically important link between collateral values and debt maturity choices. In the derivation of the relationship between a firm's labor intensity and its wage to fixed capital ratio, we critically rely on the role of fixed capital as collateral; while the acquired capital stock could be pledged as collateral, wage payments are hardly securable by creditors. Table 2 directly confirms the significance of our wage to fixed capital ratio in deciding debt maturity structures, which argues for the role of collateral values in determining optimal debt maturity policies.

This finding suggests a new economic reason why the value of collateral is important in optimal debt maturity choices. Even though prior empirical literature established a close relationship between the value of collateral and debt maturity choices (e.g. Tan et al. 2012), the existing theories paid little attention the economic rationale behind such empirical regularities. The economically significant coefficients on the wage to fixed capital ratios in Table 2 support our theoretical arguments on the relationship between collateral values and debt maturity choices.

Furthermore, Table 2 points out the significant explanatory power of our wage-fixed capital ratio in debt maturity choices, even after controlling for the asset tangibility measure. The coefficients on our wage to fixed capital ratio are 0.021, 0.017, and 0.19, respectively in the last three models that include the tangibility measure as an independent variable. This finding suggests that our wage to fixed capital ratio captures important information about the value of collateral, which is not explained by the widely used tangibility measure. This finding strengthens the validity of our theoretical analysis on the relationship between the value of collateral and optimal debt maturity choices.

Current Debt Policy

In this section, we test our empirical predictions by using another measure of debt maturity structure, the ratio between debt in current liability and total debt obligations. This measure is not only widely used as a proxy for a firm's overall debt maturity structure (Tan et al. 2012) but also closely related to its short-term debt policies (Hovakimian et al. 2001). Table 3 examines the current debt to total debt ratio as the dependent variable but employs the same set of independent variable as in Table 2 for all six models. The first model investigates a simple relation between the current to total debt obligation ratio and our wage-fixed capital ratio. The third model introduces a set of widely accepted firm characteristic variables similar to Harford et al. (2014). The fourth model additionally includes the tangibility variable, which is a balance sheet measure of collateral values. Our sixth model also controls macroeconomic conditions by using term spread, default spread and real short rates. The second and fifth models include year fixed effects to reflect the time trend of decreasing debt maturity (Harford et al. 2014). Table 3 reports the coefficients, t-values (in parenthesis) and other statistics from our estimations with robust standard errors.

Table 3 indicates that labor intensive firms tend to have a higher current debt to total debt ratio. For all six models in Table 3, the coefficients on our wage-fixed capital ratios are positively correlated with the current debt-total debt ratios. This relationship is economically significant and stable to the inclusion of other firm and macro control variables. For instance, the coefficient is 0.038 in model (1), and is 0.014 in model (6) even after controlling all firm and macro variables. In other words, one standard deviation change in our wage to fixed capital is related to 8-22 % increase in the current to total debt obligations for an average manufacturing firm. All other coefficients are in line with our estimation results reported in Table 2, which examined the economic determinants of long-term debt maturity structures.

The estimation results in Table 3 can be interpreted in a couple of ways. First of all,

Table 3: Wage/Fixed Capital and Current Debt/Total Debt

	(1)	(2)	(3)	(4)	(5)	(6)
Wage/FC	0.038***	0.039***	0.022***	0.015***	0.014***	0.014***
	(42.4)	(43.2)	(22.4)	(13.4)	(12.9)	(12.9)
Size			-0.022***	-0.023***	-0.024***	-0.024***
			(-27.4)	(-28.4)	(-27.7)	(-29.5)
M/B Ratio			0.015***	0.014***	0.011***	0.011***
			(11.2)	(10.1)	(8.2)	(8.0)
Abnormal Earnings			0.059***	0.059***	0.055***	0.058***
			(8.8)	(8.9)	(8.4)	(8.8)
Asset Maturity			-0.002***	0.001***	0.001***	0.001***
			(-8.8)	(3.7)	(3.0)	(2.7)
Book Leverage			-0.335***	-0.310***	-0.315***	-0.311***
			(-37.9)	(-34.9)	(-35.5)	(-35.0)
Rating Dummy			-0.052***	-0.053***	-0.063***	-0.058***
			(-14.4)	(-14.7)	(-16.9)	(-16.0)
Tangibility				-0.216***	-0.195***	-0.197***
				(-17.1)	(-14.9)	(-15.4)
Term Spread						0.004***
						(2.8)
Default Spread						-0.047***
						(-15.6)
Real Short Rate						-0.003***
						(-4.3)
Intercept	0.229***	0.189***	0.448***	0.499***	0.444***	0.564***
	(120.1)	(30.6)	(69.0)	(68.4)	(47.5)	(65.0)
Year F.E.	No	Yes	No	No	Yes	No
N	51070	51070	47436	47436	47436	47436
adj-R^2	0.050	0.057	0.140	0.145	0.155	0.151

This table describes the estimation results for cross-sectional models on the relationship between our wage-fixed ratio and the debt in current liabilities to total debt ratio. Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price; Book leverage is the ratio between total long term debt and book assets; The tangibility measure is the ratio of net property, plant, and equipment to total asset; Term spread,is the yield difference between one-year and ten year government bond; Default spread, the spread between AAA and BAA bonds; Real short term rate, the real interest rate for one year t-bill, The standard errors are robust to heteroskedasticity and the associated t-statistics are reported in parentheses.

the current debt to total debt ratio represents a firm's overall debt maturity structure. Under this interpretation, our finding implies a shorter debt maturity structure for labor intensive firms. Such interpretation is in line with a number of prior empirical studies such as Tan et al. (2012). Next, a higher current debt to total debt ratio is related to an active short-term debt policy. Accordingly, our findings also indicates an active short-term debt policy in labor intensive firms. This emphasis on short-term debt management is in line with the existing studies such as Hovakimian et al. (2001). They separately analyze a firm's short-term and long-term debt management in their study of leverage targeting.

The estimation results are consistent with our model predictions under both interpretations. Our theory expects that labor intensive firms are closely associated with an active short-term debt policy as well as a shorter debt maturity structure. The positive coefficients on the wage to fixed capital ratios argue for the validity of our predictions on debt maturity structure and short-term debt policy.

Our findings provide another piece of empirical evidence supporting the significant role of production technology in debt maturity choice. A firm's technology plays a pivotal role in deriving the demand of labor and capital, which crucially influences the ratio between wage payments and fixed capital. We robustly confirm that a higher wage to fixed capital ratio firm shows a more substantial amount of current debt obligations compared to its total debt obligations. Our finding differs markedly from the existing studies of debt maturity choices. This branch of literature has largely examined (1) maturity matching (Myers 1977); (2) revealing insider information to public (Diamond 1991) (3) a tool for disciple management (Jensen 1986) in optimal debt maturity policies.

The estimation results also verify an economically strong connection between collateral values and debt maturity choices. In the derivation of the relationship between a firm's labor intensity and its wage to fixed capital ratio, we critically depend on the role of fixed capital as collateral; while the acquired capital stock could be placed as collateral, wage payments are hardly securable by creditors. Table 3 directly confirms the significance of our wage to fixed capital ratio in deciding debt maturity structures, which argues for the role of collateral values in determining optimal debt maturity policies.

This finding suggests a new economic reason behind the significant role of collateral values in optimal debt maturity choices. Even though the extant empirical literature established a close relationship between the value of collateral and debt maturity choices (e.g. Tan et al. 2012), the existing theories paid limited attention to the economic factor behind such empirical regularities. The economically significant coefficients on the wage to fixed capital ratios in Table 3 argue for our theoretical arguments on the relationship between collateral values and debt maturity choices.

Moreover, Table 3 shows the significant explanatory power of our wage-fixed capital ratio in debt maturity choice again, even with the asset tangibility measure. The coefficients on our wage to fixed capital ratio are 0.015, 0.014, and 0.14 respectively in the models including the tangibility measure as one of independent variables (columns 4, 5 and 6). This finding indicates that our wage to fixed capital ratio provides a novel dimension of information related to the value of collateral, missing in the widely accepted tangibility measure. This finding reaffirms the validity of our economic arguments on the relationship between collateral value and debt maturity choices.

Note Payable Policy

In this section, we focus on the test of our model prediction related to short-term debt policy. For this purpose, we calculate the ratio between a firm's note payable and total debt obligations as a new measure of debt maturity structure. Unlike the debt in current liability, the note payable item in COMPUSTAT excludes the effect of long-term debt obligations maturing less than a year. We use cross-sectional regression models to examine our predictions as in Tables 2 and 3. While we do not report the estimation results of Tobit models that consider left censoring problems, our findings remain unchanged under the Tobit model.

Table 4 documents the estimation results using the note payable to total debt ratios as the dependent variables. The table reports the coefficients, t-values (in parenthesis) and other statistics from our estimation with robust standard errors. We employ the same independent variables as in Table 2 and 3, for all of six models. The first model investigates a simple relation between the note payable-total debt ratio and our wage-fixed capital ratio. The third model introduces widely used firm characteristic variables similar

Table 4: Wage/Fixed Capital and Short Term Debt

	(1)	(2)	(3)	(4)	(5)	(6)
Wage/FC	0.022***	0.024***	0.015***	0.012***	0.013***	0.012***
	(25.0)	(27.1)	(15.3)	(10.5)	(12.0)	(11.0)
Size			-0.009***	-0.009***	-0.004***	-0.007***
			(-11.5)	(-12.0)	(-4.2)	(-9.4)
M/B Ratio			0.000	-0.000	0.001	-0.001
			(0.2)	(-0.3)	(1.1)	(-0.4)
Abnormal Earnings			0.018***	0.018***	0.022***	0.021***
			(3.0)	(3.0)	(3.7)	(3.5)
Asset Maturity			-0.001***	-0.000	0.001***	0.000
			(-7.9)	(-0.6)	(2.8)	(0.7)
Book Leverage			-0.040***	-0.028***	-0.031***	-0.029***
			(-4.9)	(-3.4)	(-3.8)	(-3.6)
Rating Dummy			-0.034***	-0.035***	-0.045***	-0.037***
			(-10.6)	(-10.8)	(-13.6)	(-11.3)
Tangibility				-0.103***	-0.147***	-0.119***
				(-8.8)	(-12.0)	(-10.0)
Term Spread						-0.001
						(-0.8)
Default Spread						-0.012***
						(-4.3)
Real Short Rate						0.005***
						(8.6)
Intercept	0.122***	0.130***	0.207***	0.231***	0.208***	0.228***
	(69.9)	(21.1)	(33.7)	(32.7)	(22.6)	(27.0)
Year F.E.	No	Yes	No	No	Yes	No
N	51070	51070	47436	47436	47436	47436
adj-R^2	0.021	0.031	0.034	0.036	0.044	0.038

This table describes the estimation results for cross-sectional models on the relationship between our wage-fixed ratio and the note payable to total debt ratio. The dependent variable is the ratio of note payable to total debt obligations. Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price. Book leverage is the ratio between total long term debt and book assets; The tangibility measure is the ratio of net property, plant, and equipment to total asset, Term spread,is the yield difference between one-year and ten year government bond; Default spread, the spread between AAA and BAA bonds; Real short term rate, the real interest rate for one year t-bill, The standard errors are robust to heteroskedasticity and the associated t-statistics are reported in parentheses.

to Harford et al. (2014). The fourth model additionally includes the tangibility variable, which is a balance sheet measure of collateral values. Our sixth model also controls some macroeconomic conditions by using term spread, default spread and real short rates. The second and fifth models include year-fixed effects to reflect the time trend of decreasing debt maturity (Harford et al. 2014).

Table 4 clearly points out that labor intensive firms tend to exercise an active short-term debt policy. For all of the six models in Table 4, our wage-fixed capital ratios are positively correlated with the note payable-total debt ratios. This relationship is economically significant and robust to the introduction of the firm and macro control variables. For instance, the coefficient on our wage to fixed capital ratio is 0.022 in model (1) and is 0.014 in model (6) that takes account of all firm and macro variables. In other words, one standard deviation change in our wage to fixed capital is related to 16-26 % increases in the ratio of note payable to total debt obligations for an average manufacturing firm. All other coefficients are in line with our previous estimation results documented in Table 2 and 3.

The estimation results in Table 4 are well aligned with our model prediction. Our theory expects that labor intensive firms tend to show an active short-term debt policy. Accordingly, a higher wage to fixed capital ratio firm is predicted to have a significantly large amount of note payable compared to total debt obligations. The positive coefficients on our wage to fixed capital ratios support our model predictions on the relationship between the labor intensity and short-term debt policy.

Our findings argue for the importance of production technology on short-term debt managements. A firm's technology plays a crucial role in shaping the factor demand of labor and capital, which determines the budgeting problem between wage and capital acquisition. We robustly confirm that a higher wage to fixed capital ratio firm tends to exercise an active short-term debt policy. Our empirical findings argue for the importance of production technology in a firm's short-term debt policy.

The estimation results further verify an economically significant relationship between collateral values and debt maturity choices, especially in the context of short-term debt policy. As mentioned above, our construction of the wage-fixed capital ratio critically depends on the value of fixed capital as collateral; while the acquired capital stock could be used for collateral in the future, wage payments are hardly pledgeable by creditors. Hence, a firm prefers short-term debt financing for wage payments, which is relative free from collateral requirements. Table 4 directly confirms the significance of our wage to fixed capital ratio in the determination of short-term debt policy, which highlights the role of collateral values in shaping short-term debt policy.

Table 4 also shows that our wage to fixed capital ratio influences a firm's short-term debt policy, even in the presence of the tangibility measure. In the last three models, all coefficients on our wage to fixed capital ratios turn out to be statistically and economically significant. This finding reaffirms the novel information content in our wage to fixed capital ratios, which is not explained by a widely accepted collateral proxy variable, the tangibility measure. This finding reinforces the validity of our economic arguments on the relationship between collateral value and debt maturity choices.

Robustness: Period by Period Analysis

We investigate the stability of our empirical results by conducting a sub-sample period analysis. By confirming the economic significance of our estimations for different sample periods, we can assure the stability of our empirical findings in the previous sections. The time periods we cover here are, 1980s (1980 - 1989), 1990s (1990 - 1999), and 2000s (2000 - 2009). We estimate cross-sectional regressions with the three different measures of debt maturity that we proposed above. We include all firm and macro level control variables in our examinations. Table 5 reports the coefficients, t-values (in parenthesis) and other statistics from our estimations with robust standard errors.

The estimation results in Table 5 verify our empirical predictions. Labor intensive firms, measured by the wage to fixed capital ratio, tend to show a shorter long-term debt maturity structure and a more active short-term debt policy. For all three time periods across the three different measures of debt maturity, the coefficients on our wage to fixed capital ratios are all positive and statistically significant. A higher wage to fixed capital ratio firm tends to have a shorter debt maturity, a greater fraction of debt in current liabilities and a more significant amount of note payable.

Table 5: Wage/Fixed Capital and Debt Maturities - Subsample Analysis

	Long Term Maturity			Current Debt			Note Payable		
	1980s	1990s	2000s	1980s	1990s	2000s	1980s	1990s	2000s
Wage/FC	0.02***	0.02***	0.01***	0.02***	0.01***	0.01***	0.02***	0.01***	0.01***
	(6.5)	(8.6)	(6.0)	(7.9)	(6.8)	(5.6)	(7.2)	(6.7)	(6.6)
Size	-0.04***	-0.05***	-0.05***	-0.01***	-0.03***	-0.04***	0.01***	-0.00	-0.02***
	(-31.5)	(-25.6)	(-22.8)	(-8.2)	(-16.1)	(-20.4)	(5.2)	(-0.5)	(-8.6)
M/B Ratio	0.01*	0.01***	0.01***	0.01**	0.01***	0.01***	0.00	0.00**	0.00
	(1.9)	(4.6)	(2.9)	(2.1)	(6.9)	(4.7)	(0.5)	(2.0)	(0.8)
Ab. Earnings	0.01	0.05***	0.03**	0.05***	0.05***	0.07***	0.03***	0.02*	0.03***
	(0.8)	(3.9)	(2.4)	(4.5)	(4.3)	(6.2)	(2.7)	(1.8)	(2.9)
Asset Mat.	0.00***	0.00**	-0.00***	0.00***	0.00	-0.00	0.00**	0.00	0.00
	(3.1)	(2.2)	(-2.7)	(2.8)	(1.3)	(-1.1)	(2.1)	(0.6)	(0.1)
Book Lev.	-0.18***	-0.38***	-0.47***	-0.09***	-0.36***	-0.45***	0.09***	-0.05***	-0.10***
	(-11.2)	(-21.7)	(-20.8)	(-6.2)	(-23.9)	(-25.6)	(6.4)	(-3.8)	(-6.4)
Rating	-0.07***	-0.11***	-0.08***	-0.06***	-0.02***	-0.05***	-0.05***	-0.02***	-0.02***
	(-11.7)	(-14.2)	(-7.6)	(-9.7)	(-3.4)	(-6.0)	(-8.8)	(-3.7)	(-3.9)
Tangibility	-0.08***	-0.13***	-0.03	-0.28***	-0.25***	-0.07***	-0.28***	-0.18***	0.00
	(-3.2)	(-5.0)	(-0.8)	(-12.3)	(-11.4)	(-2.9)	(-12.5)	(-8.6)	(0.1)
Term Spread	0.00	0.00	0.01***	0.00	-0.01	-0.00	0.00	-0.00	-0.01**
	(0.5)	(0.6)	(3.2)	(0.2)	(-1.5)	(-0.3)	(1.1)	(-0.4)	(-2.0)
Default Spread	-0.09***	-0.02	0.04***	-0.06***	0.02	0.01	-0.03***	0.04**	0.02***
	(-14.0)	(-1.1)	(3.7)	(-9.9)	(1.3)	(1.6)	(-4.9)	(2.5)	(2.9)
Real Short Rate	0.00***	0.00	0.01***	0.00	-0.01	0.00	-0.00**	-0.00	0.00
	(4.6)	(0.6)	(3.9)	(0.1)	(-1.4)	(1.2)	(-2.0)	(-0.4)	(1.1)
Intercept	0.65***	0.78***	0.82***	0.48***	0.57***	0.61***	0.23***	0.19***	0.21***
	(36.5)	(21.4)	(36.1)	(30.6)	(17.9)	(34.0)	(15.0)	(6.1)	(12.6)
N	13197	13125	9890	15669	16326	12588	15669	16326	12588
adj-R^2	0.165	0.263	0.257	0.085	0.161	0.214	0.048	0.035	0.053

This table describes the period by period estimation results for cross-sectional models on the relationship between our wage-fixed ratio and debt maturities. The dependent variables are the fraction of long term debt obligations due in three years, the ratio of debt in curren liabilities to total debt obligations, and the ratio of note payable to total debt obligations. For each dependent variable, we investigate for three different time periods, 19980s, 1990s, and 2000s. Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price. Book leverage is the ratio between total long term debt and book assets; T Term spread,is the yield difference between one-year and ten year government bond; Default spread, the spread between AAA and BAA bonds; Real short term rate, the real interest rate for one year t-bill, The standard errors are robust to heteroskedasticity and the associated t-statistics are reported in parentheses.

It is also noteworthy that some coefficients on other control variables are not stable over the sub-sample period choices. For instance, the asset maturity variable does not have significant explanatory powers on current debt and note payable in 1990s and 2000s. The tangibility measure in long term debt maturity regression is not significant either, in 2000s. Unlike such control variables, our wage-fixed capital measure shows stably positive coefficients in all three measures of debt maturities.

These results also reinforce our emphasis on the role of production technology in debt maturity choice. A firm's production technology determines its wage to fixed capital ratio. Our findings show that this wage to fixed capital ratio robustly affects a firm's debt maturity choices regardless of the choice of sample periods. Hence, our results emphasize the significant role of production technology on debt maturity choice again.

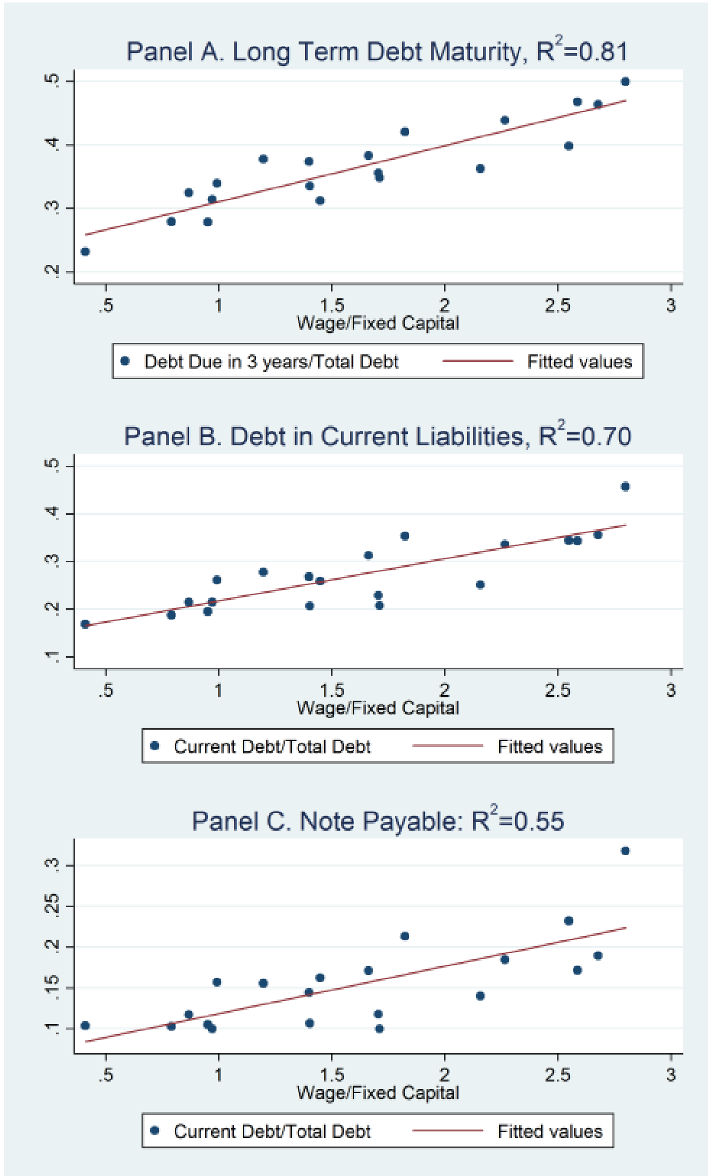
The estimation results further verify an economically significant relationship between collateral values and debt maturity choices. As demonstrated above, our construction of wage to fixed capital ratio relies on the value of fixed capital as collateral; while the acquired capital stock could be used for collateral in the future, wage payments are hardly securable by creditors. Hence, a shorter term debt financing would be more preferable to hire labor forces. Table 5 confirms the significance of our wage to fixed capital ratio in deciding debt maturity structures across a different set of sample periods. The significant coefficients on the wage to fixed capital ratios validate our theoretical arguments on the channel between the value of collateral and optimal debt maturity policies.

3.3 Empirical Results: Industry Level

The predictions of our model on debt maturity choices can be naturally extended to industry level ones, if our wage-fixed capital ratio, the measure of labor intensity, varies considerably across industries.

Before entering a comprehensive industry level analysis, we investigate a simple relationship between the labor intensity and debt maturity structures in the U.S. manufacturing industries. Figure 1 shows the scatter plot and fitted values between our wage-fixed ratio and the three different debt maturity measures for the 20 manufacturing industries.

Figure 1: Wage/Fixed Capital and Debt Maturities - Industry



This figure displays the scatter plot and fitted value of the industry debt maturities and wage fixed capital ratio for the 20 U.S. manufacturing sector. All values are averaged for each industry classification. The fraction of long term debt obligations due in three years, the ratio of debt in current liabilities to total debt obligations, and the ratio of note payable to total debt obligations are depicted against the wage to fixed capital ratio.

All values are averaged over the industry classifications based on the two digit SIC codes. Panel A plots the ratio of long term debt due in 3 years to total long term debt against our wage-fixed capital ratio. The current debt to total debt obligation ratio is depicted in Panel B. The ratio between note payable and total debt obligation is plotted in Panel C.

All of the panels in Figure 1 support our empirical predictions. The slopes shown in Panels A, B, and C are all positive, which implies a shorter debt maturity structure and a more active short-term debt policy for labor intensive industries. The amount of long term debt due in three years, debt in current liabilities, and note payable all grow as an industry level wage to fixed capital ratio increases. These findings are perfectly in line with our theoretical predictions.

The explanatory powers of our cross-sectional regression models are quite impressive as well. The wage to fixed capital ratio explains about 81% of the industry level variations in long term debt due in 3 years/total long term debt, 70% of the variations in current debt to total debt ratios, and 55% of the variations in note payable to total debt ratios. Such significant explanatory powers strengthen the validity of our empirical predictions.

Table 6 presents more concrete estimation results for our industry level analysis. All variables used in the empirical models are averaged out each year according to the two-digit SIC codes. We adopt two cross-sectional models to examine the relationship between labor intensity and industry debt maturity structures. The initial model examines a simple relationship between our wage-fixed capital ratio and the proxy variables for debt maturity structures. The next model includes other control variables such as size, future abnormal earnings, asset maturity, book leverage, market to book value ratio and tangibility measure, which are also averaged over each year in accordance with the industry classifications. The first two columns examine the industry level long-term debt maturity structure, which is defined as the ratio between long term debt obligations due in 3 years and total long term debt obligations. The next two columns adopt the ratio between debt in current liabilities and total debt obligations as the dependent variables. The last two columns analyze the note payable to total debt obligation ratio. This table reports the coefficients, t-values (in parenthesis) and other statistics from these models with robust standard errors.

Table 6 confirms a shorter long-term debt maturity structure and a more active short-

Table 6: Wage/Fixed Capital and Leverage

	Long Term Debt Maturity		Current Debt		Note Payable	
Wage/FC	0.076***	0.023***	0.074***	0.018***	0.049***	0.017***
	(17.4)	(2.8)	(21.7)	(3.0)	(14.9)	(2.8)
Size		-0.010***		-0.024***		-0.019***
		(-3.0)		(-10.0)		(-8.0)
M/B Ratio		-0.007		0.006		-0.005
		(-0.9)		(1.0)		(-0.9)
Abnormal Earnings		0.164***		0.045		-0.015
		(3.1)		(1.1)		(-0.4)
Asset Maturity		0.000		-0.002*		-0.005***
		(0.2)		(-1.7)		(-4.0)
Book Leverage		-0.334***		-0.315***		-0.082
		(-4.3)		(-5.6)		(-1.5)
Tangibility		-0.322***		-0.173***		0.028
		(-4.1)		(-3.0)		(0.5)
Intercept	0.244***	0.565***	0.148***	0.508***	0.071***	0.298***
	(30.9)	(12.3)	(24.1)	(15.1)	(12.1)	(8.9)
N	680	660	680	660	680	660
adj-R^2	0.307	0.384	0.410	0.546	0.245	0.381

This table displays the industry level estimation results for cross-sectional models on the relationship between our wage-fixed ratio and debt maturities. The dependent variables are the fraction of long term debt obligations due in three years, the ratio of debt in current liabilities to total debt obligations, and the ratio of note payable to total debt obligations. Market to book ratio is the ratio between market firm value and its book value; Asset maturity is the book value-weighted maturity of long-term assets and current assets. Future year abnormal earnings is the difference between earnings per share in year t + 1 less earnings per share in year t, divided by the year t share price. Book leverage is the ratio between total long term debt and book assets; The tangibility measure is the ratio of net property, plant, and equipment to total asset.

term debt policy in labor intensive industries. For all six models in Table 6, the coefficients on our wage-fixed capital ratios are significantly positive. For instance, the coefficients on our wage to fixed capital ratio in our simple regressions are 0.076, 0.074, and 0.049 respectively, for the three different measures of debt maturity structure. These coefficients are even far greater than their counter-parts in the firm level analysis.

The explanatory powers of our wage to fixed capital ratios in these regressions are quite impressive as well. The wage to fixed capital ratio explains 30% the industry level variations in the ratio between long term debt due in 3 years and total long term debt, 41% of the variations in the current debt to total debt ratios, and 25% variations the in note payable to total debt ratios. Such a substantially significant R^2 highlights again the importance of our wage to fixed capital ratio in the determination of debt maturity structure.

These findings present another piece of empirical evidence arguing for the importance of production technology in optimal debt maturity choices. The substantial variations in the industry level wage-fixed capital ratio indicate quite different production technology for each industry. Our empirical analysis shows a shorter debt maturity structure for labor intensive industries. This finding supports the substantial role of production technology in debt maturity choices, which is largely unexamined in existing literature.

The estimation results also verify an economically significant relationship between collateral values and debt maturity choices, even at the industry level analyses. Our construction of wage to fixed capital ratio relies on the value of fixed capital as collateral; while the acquired capital stock could be used for collateral in the future, wage payments are hardly securable by creditors. Hence, a shorter term debt financing would be more favorable to employ labor forces. Table 6 directly confirms the significance of our wage-fixed capital ratio in deciding debt maturity structures for all three different measures of debt maturity structures. The estimation results in Table 6 argue for the role of collateral values in determining optimal debt maturity policies.

Furthermore, Table 6 also confirms that our wage to fixed capital ratio influences debt maturity structure even after controlling for the tangibility measures. In our second model, all coefficients on our wage to fixed capital ratio turn out to be statistically significant even with the inclusion of tangibility measure. This finding reaffirms novel information contents in our wage to fixed capital ratios, which is not explained by a widely used collateral proxy variable, the tangibility measure. This finding reinforces the validity of our economic arguments on the relationship between collateral value and debt maturity choices as well.

4 Conclusion

This paper argued that a firm's production technology critically affects optimal debt maturity choice by shaping the factor demand for labor and fixed capital. Unlike the acquisition of fixed capital, the fund used for wage payments is hardly securable by creditors, which limits the use of longer-term debt financing to hire labor forces. Hence, a labor intensive firm with substantial wage payments is more likely to use shorter term debt contracts, which are relatively free from collateral requirements. This reliance predicts a shorter long-term debt maturity structure and an active short-term debt policy for labor intensive firms.

We tested our empirical predictions for the sample U.S. manufacturing firms. For this purpose, we introduce a measure of labor intensity, the wage to fixed capital ratio based on our theoretical arguments. Then we investigated how our measure of labor intensity is related to debt maturity choices by using the three different measures of debt maturities – the ratio of long-term debt due in 3 years to total long term debt obligations, the ratio of debt in current liability to total debt ratio, and the ratio of note payable to total debt obligations ratio. All of the estimation results are consistent with our empirical predictions. A labor intensive firm indeed shows a shorter long-term debt maturity structure and a more active short-term debt policy, exactly in line with our predictions.

Our emphasis on production technology differs markedly from the extant literature on debt maturity choices. These studies have largely examined the debt maturity choice from the perspective of agency problems. Matching maturities (Myers 1977), revealing insider information to public (Diamond 1991), and disciplining managerial incentives (Jensen 1986) are representative economic arguments about debt maturity choices. In contrast, we directly show a close relationship between production technology and optimal debt maturity choices by investigating the role of factor demands for labor and fixed capital in the determination of debt maturity structure.

Our analysis also provides a new economic reason why the value of collateral possibly changes optimal debt maturity policies. Even though the role of collateral values on debt maturity choice is well documented in the existing empirical literature (e.g. Tan et al. 2012), there is no concrete economic theory that connects collateral values with debt maturity choice. Our analysis clearly shows that a firm's collateral value matters significantly in optimal debt maturity structure via a firm's budgeting problem in the purchase of labor and fixed capital.

This emphasis on production technology opens a new venue for studying the implications of other production components. For instance, a firm may need a significant amount of intermediary goods for its production, which is hardly pledgeable as well. Because such importance of raw materials may show up in a firm's inventory item, we could predict an economic relationship between inventories and debt maturity structure analogous to the relationship between wage payments and debt maturity choices. Moreover, the financing of intermediary goods is closely associated with a firm's working capital management. It is worthwhile investigating the role of overall working capital management in determining debt maturity structures. These topics are beyond the scope of this paper and are left to future research.

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Appendix

A Appendix

Let us denote that K_0^*, K_1^*, and K_{1s}^*,are optimal capital stock at time $t = 0, t = 1$, and $t = 1$ with financial market freeze, respectively. L_0^*, L_1^*, and L_{1s}^*,represent optimal labor policies, which are similarly defined.

There are three financing sources for the acquisition of initial physical capital, K_0^*. Equity (E_0^K), one-period debt contract ($D_{0,1}^K$) and collateralized two-period debt contract ($D_{0,2}^K$) are available. For the second cycle operation, only the capital stock purchased from the equity (E_0^K) and two period debt contract ($D_{0,2}^K$) remain because the pledged capital stock for one-period debt ($D_{0,1}^K$) pays back to the creditors. E_1^K and E_{1s}^K represent the net flow of equity at $t = 1$ for the state with/without financial market freeze. In the case of capital acquisition, the net flow of equity at $t = 1$ becomes positive. On the other hand, if the firm resales its capital stock at $t = 1$, the net equity flow becomes negative. The firm is able to use one-period collateralized debt contract ($D_{1,2}^K$) at $t = 1$ only for the economic state without incurring financial market freeze.

A.1 Optimal Capital Financing

The financing decisions of the firm's optimal capital stock can be represented by the following equations.

$$
\begin{aligned}
K_0^* &= E_0^K + D_{0,1}^K + D_{0,2}^K \\
K_1^* &= E_0^K + E_1^K + D_{1,2}^K + D_{0,2}^K \\
K_{1s}^* &= E_0^K + E_{1s}^K + D_{0,2}^K \\
E_0^K + E_1^K &\geq 0 \\
E_0^K + E_{1s}^K &\geq 0 \\
E_0^K &\geq 0 \\
E_1^K &\leq 0
\end{aligned}
$$

The sum of the first and second period equity$\left(E_0^K + E_1^K \text{ and } E_0^K + E_{1s}^K\right)$ cannot be smaller than zero due to the collateral requirements for debt contracts. We can easily prove that E_1^K cannot be positive in a optimal allocation; we could find a better policy by setting $\bar{E}_1^K = 0$ and $\bar{D}_{1,2}^K = D_{1,2}^K - \bar{E}_1^K$ without incurring other policy changes. It is always better to use debt rather than equity because the cost of debt is less expensive than that of equity.

Proposition 5 *In an optimal policy,* $min\left(E_0^K + E_1^K, E_0^K + E_{1s}^K\right) = 0$
Proof. *Suppose that* $\varepsilon = min\left(E_0^K + E_1^K, E_0^K + E_{1s}^K\right) > 0$, *Let us define* $\bar{E}_0^K = E_0^K - \varepsilon$, $\bar{D}_{0,2}^K = D_{0,2}^K + \varepsilon$. *In this allocation, the firm reduces initial equity financing by* ε *but increases interest payments* εr *at* $t = 1$ *and additionally pay back interests and principal at* $t = 2$. *The total valuation effect is*

$$\begin{aligned} \varepsilon - \frac{r\varepsilon}{1+\rho} - \frac{(1+r)\,\varepsilon}{(1+\rho)^2} &= \frac{\varepsilon(1+\rho)^2 - r\varepsilon(1+\rho) - (1+r)\,\varepsilon}{(1+\rho)^2} \\ &> \frac{\varepsilon(1+\rho) - (1+r)\varepsilon}{(1+\rho)} > 0. \end{aligned}$$

Accordingly, $\varepsilon = 0$. ■

We further assume that $K_0^* \geq \max(K_1^*, K_{1s}^*)$ to characterize the following optimal policies, Cases 1 and 2.

Case 1 $K_0^* \geq K_1^* \geq K_{1s}^*$

This condition implies that $E_0^K + D_{0,1}^K \geq E_0^K + E_1^K + D_{1,2}^K \geq E_0^K + E_{1s}^K \geq 0$.

We firstly argue that $E_0^K + E_{1s}^K = 0$. Proposition 1 indicates either $E_0^K + E_1^K = 0$ or $E_0^K + E_{1s}^K = 0$. Suppose $E_0^K + E_{1s}^K > 0$. It implies that $E_0^K + E_1^K = 0$, then the above inequality reduces to $E_0^K + D_{0,1}^K \geq D_{1,2}^K \geq E_0^K + E_{1s}^K = \varepsilon_1 > 0$. We have two possible cases for E_{1s}^K.Consider $E_{1s}^K \geq 0$ first. The positive equity financing for the capital stock at time $t = 1$ with liquidity shock implies $D_{0,1}^K \geq E_{1s}^K$ and $D_{1,2}^K \geq E_{1s}^K$. Then we can find a new policy where $\bar{D}_{0,2}^K = D_{0,2}^K + E_{1s}^K . \bar{D}_{1,2}^K = D_{1,2}^K - E_{1s}^K, \bar{D}_{0,1}^K = D_{0,1}^K - E_{1s}^K$, and $\bar{E}_{1s}^K = 0$. Then the new policy increases the value of firm by replacing equity financing E_{1s}^K with a two-period debt financing by $\bar{D}_{0,2}^K = D_{0,2}^K + E_{1s}^K$. Therefore, $E_0^K + E_{1s}^K = 0$

Next, we investigate the policy of $E_{1s}^K < 0$.Then the size of optimal capital stock implies $E_0^K + D_{0,1}^K \geq D_{1,2}^K \geq E_0^K + E_{1s}^K = \varepsilon > 0$. Let us consider another policy where $\bar{E}_0^K =$

$E_0^K - \varepsilon_1, \bar{D}_{0,2}^K = D_{0,2}^K + \varepsilon_1, \bar{E}_1^K = -E_0^K$,and $\bar{E}_{1s}^K = 0$. This new policy is better off from the perspective of shareholders because it reduces initial equity financing by the amount of ε with a two-period debt contract. Thus, $E_0^K + E_{1s}^K = 0$.

Accordingly, we only need to consider the following allocations.

$$\begin{aligned} K_0^* &= E_0^K + D_{0,1}^K + D_{0,2}^K \\ K_1^* &= E_0^K + E_1^K + D_{1,2}^K + D_{0,2}^K \\ K_{1s}^* &= D_{0,2}^K \\ E_0^K + E_1^K &\geq 0 \\ E_0^K &\geq 0 \\ E_1^K &\leq 0 \end{aligned} \tag{2}$$

Now we want to prove $E_0^K + E_1^K = 0$. Suppose $E_0^K + E_1^K = \varepsilon_2$.Then we find another policy where $\bar{E}_0^K = -\bar{E}_{1S}^K = E_0^K - \varepsilon_2, \bar{D}_{0,1}^K = D_{0,1}^K + \varepsilon$, and $\bar{D}_{1,2}^K = D_{1,2}^K + \varepsilon_2$. By replacing equity financing with one-period debt contract by the amount of ε, the shareholders become better off. Hence, no equity financing occurs at $t = 1$.

Lastly, we want to prove $\mathrm{E}_0^K = 0$. Suppose $E_0^K = \varepsilon_3$. Then we construct another policy where $\bar{E}_0^K = -\bar{E}_{1s}^K = -\bar{E}_{1S}^K = 0$ and $\bar{D}_{0,1}^K = D_{0,1}^K + \varepsilon_3$. By substituting debt financing for initial equity financing, the shareholder value of firm increase as well. Thus $\mathrm{E}_0^K = 0$.

To sum up, the firm's optimal capital financing only depends on debt contracts:

$$\begin{aligned} K_0^* &= D_{0,1}^K + D_{0,2}^K \\ K_1^* &= D_{1,2}^K + D_{0,2}^K \\ K_{1s}^* &= D_{0,2}^K. \end{aligned}$$

Now, we turn to prove $D_{1,2}^K = 0$.

Case 2 $K_0^* \geq K_{1s}^* \geq K_1^*$

This condition implies that $E_0^K + D_{0,1}^K \geq E_0^K + E_{1s}^K \geq E_0^K + E_1^K + D_{1,2}^K \geq E_0^K + E_1^K \geq 0$. We want to firstly argue $E_0^K + E_1^K = 0$. Suppose $E_0^K + E_1^K = \varepsilon_4 > 0$. Proposition 1 also indicates $E_0^K + E_{1s}^K = 0$. Find another policy where $\bar{E}_0^K = E_0^K - \varepsilon_4, \bar{E}_1^K = 0, \bar{E}_{1S}^K = -\bar{E}_0^K$

and $\bar{D}_{0,1}^K = \bar{D}_{0,1}^K + \varepsilon$. By replacing initial equity contract with one period debt contract with the amount of ε_4, the firm's equity value enhances.

With $E_0^K + E_1^K = 0$, the firm's capital financing problem becomes:

$$\begin{aligned} K_0^* &= E_0^K + D_{0,1}^K + D_{0,2}^K \\ K_1^* &= D_{1,2}^K + D_{0,2}^K \\ K_{1s}^* &= E_0^K + E_{1s}^K + D_{0,2}^K \\ E_0^K + E_{1s}^K &\geq 0 \\ E_0^K &\geq 0 \end{aligned}$$

Under this circumstance, we can prove $E_0^K = 0$. Suppose $E_0^K = \varepsilon_5 > 0$. Yet, the shareholders could increase the value of firm by setting $\bar{E}_0^K = 0, \bar{D}_{0,1}^K = D_{0,1}^K + \varepsilon$, and $\bar{E}_{1s}^K = E_{1s}^K + \varepsilon_5$. This policy replaces initial equity financing with one-period debt contract.

Then our inequality of $K_0^* \geq K_{1s}^* \geq K_1^*$ comes down to $D_{0,1}^K \geq E_{1s}^K \geq D_{1,2}^K$. Under this circumstance, we can prove $D_{1,2}^K = 0$. Suppose $D_{1,2}^K > 0$. Then we can find another policy $\bar{D}_{1,2}^K = 0, \bar{D}_{0,1}^K = D_{0,1}^K - D_{1,2}^K, \bar{D}_{0,2}^K = D_{0,2}^K + D_{1,2}^K$, and $\bar{E}_{1s}^K = E_{1s}^K - D_{1,2}^K$.Then by reducing equity financing at the state of financial market freeze, the value of firm increases.

To sum up, the firm's optimal capital financing has the following formulations:

$$\begin{aligned} K_0^* &= D_{0,1}^K + D_{0,2}^K \\ K_1^* &= D_{0,2}^K \\ K_{1s}^* &= E_{1s}^K + D_{0,2}^K \end{aligned} \tag{3}$$

Equity is used for the purchase of capital stock only for the state of financial market freeze.

A.2 Optimal Policies

Optimal Policy without Financial Market Freeze

This section describes the optimal policy without the consideration of financial market freeze. In this case, the possibility of strategic default limits the use of debt financing, at least the second period wage payments. Yet, there is no incentive to use two-period debt because cost of debt are constant irrespective of debt maturity structure. Therefore, the firm is able to use one-period collateralized debt financing for capital acquisition, one-period uncollateralized one period uncollateralized debt for initial wage payments (if possible) and the equity financing for the second period wage payments.

Then the optimal capital and labor policy becomes the solution of following maximization problem.

$$
\begin{aligned}
& \max_{K,L_1,L_2} \frac{1}{1+\rho}\left[\pi_1 + \frac{1}{(1+\rho)}\pi_2\right] \\
\pi_1 &= \theta K_0^\alpha L_0^\beta - (1+r)wL_0 - rK - wL_1 \\
\pi_2 &= \theta K_1^\alpha L_1^\beta - rK_1.
\end{aligned}
$$

The firm has to pay $(1+r)wL_0$ because we assume that the uncollateralized debt financing is available for initial wage payments. Then the first order conditions are

$$
\begin{aligned}
K_0 &: \theta\alpha K_0^{\alpha-1}L_0^\beta = r \\
K_1 &: \theta\alpha K_1^{\alpha-1}L_1^\beta = r \\
L_0 &: \theta\beta K_0^{\alpha}L_0^{\beta-1} = (1+r)w \\
L_1 &: \theta\beta K_1^{\alpha}L_1^{\beta-1} = (1+\rho)w
\end{aligned}
$$

Then the optimal labor and capital policies are:

$$
\begin{aligned}
K_0^* &= \left(\frac{\theta\alpha}{r}\right)^{\frac{1-\beta}{1-\alpha-\beta}}\left(\frac{\theta\beta}{w(1+r)}\right)^{\frac{\beta}{1-\alpha-\beta}} \\
K_1^* &= \left(\frac{\theta\alpha}{r}\right)^{\frac{1-\beta}{1-\alpha-\beta}}\left(\frac{\theta\beta}{w(1+\rho)}\right)^{\frac{\beta}{1-\alpha-\beta}} \\
L_0^* &= \left(\frac{\theta\alpha}{r}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{\theta\beta}{w(1+r)}\right)^{\frac{1-\alpha}{1-\alpha-\beta}} \\
L_1^* &= \left(\frac{\theta\alpha}{r}\right)^{\frac{\alpha}{1-\alpha-\beta}}\left(\frac{\theta\beta}{w(1+\rho)}\right)^{\frac{1-\alpha}{1-\alpha-\beta}}.
\end{aligned}
$$

Hence, $K_0^* > K_1^*$.

$$\frac{K_0^*}{K_1^*} = \left(\frac{w(1+\rho}{w(1+r)}\right)^{\frac{\beta}{1-\alpha-\beta}} > 1$$

Optimal Policy with Financial Market Freeze

The optimal capital and labor policy with financial market freeze cannot be better off than those without financial market freeze. Yet, the manager still achieves the optimal policy without financial market freeze by setting $D_{0,2}^K = K_1^* = K_{1s}^*$ and $D_{0,1}^K = K_0^* - K_1^*$. Furthermore this is only one optimal policy in this economic environment based on the equations (1) and (2); these equations indicate that there are no optimal policy other than $D_{0,2}^K = K_1^* = K_{1s}^*$ and $D_{0,1}^K = K_0^* - K_1^*$, if $K_0^* > K_1^* = K_{1s}^*$. This argument proves Proposition 5. Accordingly, the firm's optimal policy becomes irrelevant to the realization of financial market freeze as described in Proposition 2.

Proof of Proposition 3

The representative firm's one-period debt to two period debt ratio at $t = 0$ is

$$\begin{aligned}\frac{wL_0 + K_0 - K_1}{K_1} &= \left(\frac{wL_0}{K_0} + 1\right)\left(\frac{K_0}{K_1}\right) - 1. \\ &= \left(\frac{r\beta}{(1+r)\alpha} + 1\right)\left(\frac{1+\rho}{1+r}\right)^{\frac{\beta}{1-\alpha-\beta}} - 1,\end{aligned}$$

where the second equality comes from the firm's first order conditions and optimal policies.

Furthermore, if you take logarithm of $\left(\frac{r\beta}{(1+r)\alpha} - 1\right)\left(\frac{1+\rho}{1+r}\right)^{\frac{\beta}{1-\alpha-\beta}}$ and calculate the derivative with respect to β, we could show that this derivative is always positive.

$$\frac{d}{d\beta}\log\left(\frac{r\beta}{(1+r)\alpha} + 1\right)\left(\frac{1+\rho}{1+r}\right)^{\frac{\beta}{1-\alpha-\beta}} = \frac{d}{d\beta}\log\left(\frac{r\beta}{(1+r)\alpha} + 1\right) + \frac{\beta}{1-\alpha-\beta}\log\left(\frac{1+\rho}{1+r}\right) > 0$$

This argument proves Proposition 3.

Proof of Proposition 4

If a firm's continuation value is greater than the value of strategic default, the following inequality has to be satisfied:

$$\left(\theta K_0^{\alpha} L_0^{\beta} - (1+r)wL_0 - rK_0 - wL_1\right) + \frac{1}{1+\rho}\left(\theta K_1^{\alpha} L_1^{\beta} - rK_1\right) \geq \theta K_0^{\alpha} L_0^{\beta}.$$

The first term in the left hand-side variable represents the profits after initial debt payments and wage payments at $t = 1$. The second term in the left hand side term is the profits after interest payments at $t = 1$. The right hand side variable is the value of strategic default, the operating profits at $t = 1$. Based on the optimal policies described above, the inequality can be rewritten as

$$1 \geq (\alpha+\beta) + (1+\rho)(\alpha+\beta)\left(\frac{1+\rho}{1+r}\right)^{\frac{1}{1-\alpha-\beta}}$$