Roll-Over Risk and the Choice of Cash Holdings, Debt Maturity and Leverage*

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Abstract

This paper empirically examines the joint choice of corporate cash holdings, leverage and debt maturity. We document a nonlinear relationship between cash holdings and debt maturity. We find that firms accumulate more cash when their debt maturity concentrates either in the short- or the long-end, however the cash holdings come from different sources. Cash reserves are more likely to come from bond financing when the debt maturity is longer. Using the 2007 credit crunch as an exogenous shock, we find evidence that firms with ex-ante longer debt maturity invest more after the financial crisis than firms with shorter maturity debt.

Keywords: Corporate Liquidity Management, Debt Maturity Structure, Leverage, Roll-Over Risk, GMM, Panel Data
JEL Classification: G01, G31, G32

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1 Introduction

Liquidity management and debt financing are critical decisions for firms' operations and they are likely to be jointly determined. In a Miller-Modigliani frictionless world, the liquidity management is irrelevant since debt is negative cash and firm is able to raise money through borrowing at any time. However, firms' access to the credit market is imperfect in the real world. This imperfection motivates a precautionary hoarding of cash as Keynes (1936) points out: a firm can use internal funds to hedge against future external funds shortage. A natural question then is, should firms issue debt to finance their cash reserves? In particular when holding cash earns a lower return than borrowing costs. The answer is yes, but only when the debt is long term. The intuition is that firms that hoard cash by issuing short-term bonds do not enjoy the hedging benefit, because they must pay off their debt first when credits contract. On the other hand, when the outstanding debt matures in longer horizon, cash hoarding firms effectively transfer future resources into today and is able to capture value-enhancing investment opportunities when external funds are costly to obtain in the near term.

In this paper, we empirically examine firms' liquidity management and debt financing decisions jointly. Our theoretical framework is a modified version of the international finance model developed by Bianchi et al. (2012). One insight from their model is that countries will accumulate cash reserves to hedge against sudden stop risk, and smooth household's consumption stream with long-term borrowing. In our model, a representative firm maximizes the present value of dividend payout lives for three periods. In the first period, the firm makes financing decisions, knowing that with a certain probability the credit market will shut down next period. When the intermediate period arrives, the firm faces a valuable investment opportunity that will generate profits in the last period. If the firm borrows only short-term at the beginning, then in the intermediate period when the borrowing constraint binds, the firm has no resources to invest after paying off their outstanding debt, and will receive no profits in the last period. However, if the firm borrows long-term and build up a cash reserve at first, then without debt capacity in the intermediate period, it can use its cash holdings to invest and earn a return at last to pay off their long-term debt obligations. In this way, a firm effectively transfer future resources into the present to capture positive NPV projects without external funding.

Although it is not optimal for firms to borrow short-term and hoard cash, firms will hold cash when the fraction of maturing debt is high. Harford et al. (2014) argues that to mitigate refinancing risk caused by short debt maturity, firms increase their cash holdings by saving more cash from their cash flows. This consideration gradually decreases as debt maturity moving toward the long-end. As a result, the rollover risk plays two roles to determine cash holdings and debt maturity. On the one hand, when the debt maturity is short, firms hold more cash to repay their maturing liabilities. On the other hand, firms borrow long-term and maintain cash reserves. This leads us to hypothesize there exists a nonlinear relationship between cash holdings and debt maturity, and cash reserves come from different sources depending on outstanding debt maturity.

We propose the following hypotheses. First, we expect firms' cash holdings has a "U" shape relationship with its outstanding debt maturity structure in normal times. Second, debt maturity is positively correlated with firm leverage. Finally, after credit falls short, firms with longer maturity structures ex-ante should draw down more on their cash reserves to invest relative to their peers with shorter maturity structures. We evaluate these model predictions using a sample of U.S. firms from COMPUSTAT spanning two decades, 1992 through 2012. We pick this time period because our test requires an exogenous credit contraction shock. As documented in numerous studies, the 2007 financial crisis provides such a cross country exogenous credit squeeze in the U.S. bond market. Quantitatively, according to Almeida et al. (2009), "the total debt issuance with maturity greater than one year for the third quarter of 2007 amounted to \$63 billion, while the average quarterly amount of funds raised in the bond market in the two years preceding the crisis was \$337 billion." During our sample period, there is no other obvious credit shortage crisis. Arguably the 2001 recession is a demand shock rather than a supply shock. We then divide the sample period into two sub-periods, ex-ante and post 2007 crisis. Using a simultaneous equation model that account for the joint determination of cash holdings and debt maturity, we find a significant "U" shape relationship between cash holdings and debt maturity structure. We also find evidence of the positive relationship between leverage and debt maturity. To examine the effects of debt maturity on post-crisis firm behaviors, we exploit the ex-ante variations in firms' debt maturity structures. More specifically, we assign firms with long-term debt to total debt ratio above a certain threshold in 2006 to a treatment group, and construct a dummy variable with 1 for firms in the treatment group and in year 2007. Finally we re-run the simultaneous equations regression with the treatment dummy using the full sample and control for all the firm characteristics and firm-year fixed effects. The coefficient of treatment dummy variable indicates the difference-in-difference effect of treatment group after credit squeeze. Our result shows that after the negative credit supply shock, firms with ex-ante longer maturity structure significantly reduce their cash holdings, increase their investments compared to firms with shorter ex-ante maturity structure.

2 Related Literature

Our model shares some mechanisms with the model in Bianchi et al. (2012), but their research question is at country level cash reservers and roll-over risk. They calibrate their model to Mexico's time series data and do not test their model implications, in contrast, we conduct our empirical analysis with a large U.S. firm-level panel and statistically test our hypotheses. A few studies have examined the relationship between ex-ante firm characteristics and ex-post firm behaviors using the 2007 financial crisis as an exogenous shock. Duchin et al. (2010) argues that firms experience greater investment declines when they have lower cash reserves and higher short-term debt before the onset of the crisis. A similar relationship is shown in Almeida et al. (2009), but they emphasize a more experimental strategy to argue the causal effect of debt maturity structure on firm decisions. Consistent with these studies, we also find a greater decline in investment for firms with shorter debt maturity structures. Our contribution is that we jointly analyze firm's financing and liquidity management decisions to generate richer predictions. Then we find empirical evidence that support our hypothesis.

This paper also relates to the literature on the determinants of corporate cash holdings. The precautionary motive has been proposed and tested in a number of papers, such as Opler et al. (1999) and Han and Qiu (2007). Nevertheless, few paper closely investigate the hedging motive against roll-over risk. Acharya et al. (2007) proposes a hedging benefit of debt, but they do not fully consider the impacts of debt positions. In this respect, this paper extends the hedging perspective to incorporate different debt maturity structures.

Finally, Harford et al. (2014) jointly estimates cash holdings and debt maturity and finds a negative relationship. They argue that firms will save more cash when the amount of debt maturing is large because when firms are unable to refinance their debt, cash reserves help to repay. Nevertheless, this relationship is not linear. As debt maturity moves to the long-end, another benefit to accumulate cash emerges. When facing uncertain credit conditions, firms will borrow long-term to reallocate resources across time to seize growth opportunities when experiencing roll-over difficulties. Consequently, the relationship is nonlinear between cash holdings and debt maturity with cash holdings highest at either end of maturity and lowest at medium-term.

3 Model

A firm lives for three period, $t = 0, 1, 2$. The firm can issue debt of either one-period or multi-period at period 1 and two. We only allow firm to accumulate cash at the first period and invest in a one-period project at the second period. The firm faces a roll-over risk at time $t = 1$. If the sudden liquidity dry up hits the economy at the intermediate date, the firm will not be able to borrow from the debt market. We assume that the firm cannot issue equity to finance their needs and cannot default on their debt.

The firm maximizes its lifetime dividend payoff:

$$max : d_0 + d_1 + d_2 \tag{3.1}$$

subject to budget constraints at each period:

$$d_0 + a \leq q_0 b_0, \tag{3.2}$$

$$d_1 + I_1 \leq a(1 + r_a) - b_0 + b_1, \tag{3.3}$$

$$d_2 + (1 - \delta)b_0 + b_1 = f(I_1). \tag{3.4}$$

The corporate debt structure is the following: b_0 is the multi-period debt issuance at period 0 and b_1 is the debt issuance at period 1. The multi-period debt is defined as a consol with a coupon "decay" factor $1 - \delta$. The debt issued at time t is assumed to pay $(1 - \delta)^j$ dollars $j + 1$ periods in the future. When $1 - \delta$ is high, it means the coupon payments decay slowly and the cash flows are more spread out into the far future. On the other hand, when $1 - \delta$ is low, the coupon payments decay fast and the cash flows are concentrated in the near future. I use this specification to mimic the cash flow streams of bonds with different maturities. Bonds with higher $1 - \delta$ represents longer maturities. Hence, by altering the value of $1 - \delta$, we can model the maturity structure of outstanding government debt using only one parameter. In extreme case $1 - \delta = 0$, the debt portfolio collapses to one-period debt and if $1 - \delta = 1$, it becomes a consol.

a is the amount of cash holding the firm chooses and I_1 is the investment the firm makes at period 1. This investment will return $f(I_1)$ at the final period where $f(\cdot)$is the production function satisfies the usual properties such as $f'(\cdot) < 0$ and $f''(\cdot) > 0$. r_b is the rate of return on corporate bond and r_a is the rate of return on cash holding. We assume that $r_b > r_a$. q_0 is the bond price at period 0. By no arbitrage condition, the price of a bond at any period should equal to the present value of all the future coupon payments. Therefore, $q_0 = \frac{1}{1+r_b} + \frac{1-\delta}{(1+r_b)^2}$.

When the sudden liquidity contraction hits the economy, the firm cannot roll over its debt at period 1. In this case $b_1 = 0$. And it is never optimal for the firm to distribute dividends at the first two periods. So we can rewrite firm's problem as:

$$max : d_2 = f(I_1) - (1 - \delta)b_0 \tag{3.5}$$

subject to

$$a = q_0 b_0 \geq 0, \tag{3.6}$$

$$I_1 = a(1 + r_a) - b_0 \geq 0, \tag{3.7}$$

Substituting I_1 and a in the utility using the budget constraint, we get:

$$f[(q_0 b_0)(1 + r_a) - b_0] - (1 - \delta)b_0, \tag{3.8}$$

Combining constraints (3.6) and (3.7) yields,

$$q_0(1 + r_a) - 1 \geq 0, \tag{3.9}$$

Plug $q_0 = \frac{1}{1+r_b} + \frac{1-\delta}{(1+r_b)^2}$ into (3.9) to get,

$$\frac{1 + r_a}{(1 + r_b)^2} + (\frac{1 + r_a}{1 + r_b} - 1)\frac{1}{1 - \delta} \geq 0, \tag{3.10}$$

The first order condition with respect to b_0 is:

$$f'(I_1) = \frac{1 - \delta}{q_0(1 + r_a) - 1}, \tag{3.11}$$

Plugging in the bond price for q_0 to get:

$$f'(I_1) = \frac{1}{\frac{1+r_a}{(1+r_b)^2} + (\frac{1+r_a}{1+r_b} - 1)\frac{1}{1-\delta}}. \tag{3.12}$$

Proposition 1. *For firms face uncertainty in rolling over their debt, the longer their outstand-*

ing debt maturity $\delta \downarrow$, the greater amount they hold cash reserves $a \uparrow$ and debt $b_0 \uparrow$ prior to a credit contraction. Ex-post they draw down more cash reserves and invest more $I_1 \uparrow$.

Detailed proof is in Appendix A. The intuition behind goes as the following. When firms face roll-over risk, they would like to hoard cash for precautionary motive. However, if they can only accumulate cash by borrowing, then they will only do so when the debt contracts are longer period. Borrowing one-period cannot transfer resources across time and hence firms are no better off. Firms that can borrow longer terms do not have immediate pressure for repaying their debt, so they borrow more, and then save more cash out of their borrowing to hedge against uncertain credit shortage. When the credit market suddenly dries up, they use those precautionary cash holdings to finance their investment needs.

On the other hand, suppose firms that borrow long-term now has debt maturing soon, so they need to hold funds to pay back the outstanding liabilities in case their projects do not generate enough return and have difficulties rolling-over their debt. This implies that in the data, one is likely to observe that shorter debt maturity is associated with more cash holdings. Harford et al. (2014) confirms this prediction. They find that firms with shorter maturity debt increase their cash holdings and save more cash from their cash flows to mitigate refinancing risk.

Overall, debt maturity has a nonlinear effect on cash holdings. When we observe firms with relatively shorter debt maturity, it is more likely for them to hold more cash in order to repay maturing debt, less likely to hold cash out of their borrowing to capture investment opportunities. As the debt maturity moves toward the long end, firms are more likely to reserve cash out of their borrowing to meet investment need, less likely to meet liabilities repayment requirement. Consider two polar cases to understand the tradeoffs. The first case is a firm with all debt maturing next period, facing a refinancing risk, the firm will save more cash from internal funds to be able to pay back their liabilities in case of financing constrained next period, but not to borrow short-term to finance their future investment. The other extreme case is a firm with no debt maturing next period, while it is no pressure for the firm to save cash to retire debt in the near future, the firm will apt to save cash to reallocate resources across time to avoid forgone positive NPV projects. The marginal benefits are highest at either end of the maturity structure such that we hypothesize a "U" shape relationship between maturity and cash holdings.

4 Empirical Design

This paper explores the effects of corporate debt maturity on firm's financial and real decisions when firm faces rollover risk. The model from last section predicts that firms with longer maturity in their outstanding debt tend to borrow more against their far future resources and save more cash today to cushion an uncertain credit constraint in the future. On the other hand, firms with more maturing debt have an urge to hold cash for their forthcoming due liabilities. Thus, we hypothesis that there exists a "U" shape relationship between cash holdings and debt maturity such that firms reserve more cash at either end of maturity prior to a negative credit supply shock. After a credit crisis hits the economy, firms with longer maturity ex-ante are able to offset the impacts of the negative credit shock using cash reserves, therefore seize more investment opportunities during the crisis. We use the 2007 financial crisis, an exogenous credit supply contraction shock, as a realization of rollover risk to test our hypotheses ex-ante and ex-post.

In section 5.1, we first investigate the prior crisis joint relationship between firm's debt maturity structure and cash holdings predicted using simultaneous equations models in which cash holdings and maturity are treated as endogenous. We follow Johnson (2003) and Billett et al. (2007) in specifying our maturity equation. We include firm size, leverage, asset maturity, debt rating dummy, term spread, net debt issuance and year dummies. In the cash holding equation, we follow Bates et al. (2009) and Harford et al. (2014) to include Tobin's Q, firm size, cash flow, net working capital, capital expenditure, R&D expense, dividend dummy, acquisition expense, leverage, net debt issuance and year dummies. Most of these explanatory variables are motivated by transaction and precautionary implications for cash holdings that are common in previous literature. We also add the square of debt maturity to the cash holdings equation to test for the nonlinearity between cash holdings and debt maturity. The focus of this paper is the coefficient in front of the debt maturity and square of debt maturity variables. The estimation is implemented using Maximum Likelihood (ML) method. Borrowing from Billett et al. (2007), we then run a single equation regression of leverage against maturity, firm size, Tobin's Q, cash flow, tangibility, abnormal earnings and year dummies in which maturity is instrumented by debt rating dummy and term spread.

In section 5.3, we examine the ex-post real effects on firms due to their ex-ante variations in debt maturity structure. We first split the firms into two sub-groups according to the debt maturity profile right before the onset of the financial crisis and assign one group to be treatment group and the other to be control group. Then we create a treatment dummy that equals 1 if the observation belongs to the treatment group and if in crisis period. We regress dependent variables against this treatment dummy and other control variables. Then we repeat the simultaneous equations models and single equation instrumental variable regression used in section 5.1 but add the treatment dummy into the cash holdings and leverage equations. This differences-in-differences in a panel regression approach directly compares the changes in outcome variables between those two groups.

We list detailed variable definitions in section 4.1.

4.1 Variable Construction The data used in this paper come from COMPUSTAT's North America Fundamentals Annual for fiscal year 1992 to 2012. The whole sample contains 117,799 firm-year observations for 9,674 unique firms. We separate the sample period into two sub-period, one prior to the 2007 financial crisis and the other post crisis period. The ex-ante period is chosen because no significant credit supply contraction happened during that time horizon despite a demand-driven recession in 2001. Therefore, firms should hold more cash for hedging motive if the outstanding debt maturity structure is at either end of the maturity structure, controlling for other firm characteristics. The prior crisis period contains 70,881 firm-year observations for 7,259 unique firms. As in Opler et al. (1999), we exclude observations from utilities (SIC codes 4900-4999) because their cash holdings may subject to additional regulation. We also exclude financial institutions (SIC codes 6000-6999), not-for-profit organizations, and governmental enterprises (SIC cods greater than 8000). We require firms have positive assets (at), sales (sale), property, plant and equipment (ppent) and capital expenditure (capx) in any given year. Further, we only keep firms that have positive cash holdings (che) and short- and long-term debt outstanding (dlc and dltt). The firm level data is then matched with bond term premium which is computed as the difference between the month-end yields on a 6-month treasury bill and a 10-year constant maturity treasury bond and debt rating dummy which is 1 for every firm-year observation that has long-term bond rating. The term premium is matched to the month of a firm's fiscal year-end. The bond yields data comes from the Federal Reserve Bank of St. Louis's economic database (FRED) and the debt rating data is from COMPUSTAT's Monthly Updates - Ratings data base.

We further restrict firm's leverage ratio to be bounded between zero and one. To deal with potential outliers in the sample, we winsor cash/assets, market to book ratio, cash flow/assets, NWC/assets, capital expenditure/assets, R&D/sales, acquisitions/assets, issuance/assets, tangibility/assets and maturity at 1% level. The variables are measured in the following ways:

Cash: Cash holdings is defined as the ratio of cash and short-term investments (che) to total assets.

Tobin's Q: The ratio of total assets (at) plus the market value of equity (prcc*csho) minus the book value of equity (ceq) and deferred taxes (txdi) and investment tax credit (itci) to the book value of assets (at). The higher value of Q, the more investment opportunities that firm faces.

Firm Size: Size is defined as the log of total assets (at). It is normalized to 2005 dollars.

Cash Flow: Cash flow is measured as the ratio of income before extraordinary items (ib) plus depreciation and amortization (dp) to total assets (at).

Maturity: Following Barclay and Smith (1995), Johnson (2003) and Billett et al. (2007), maturity structure is measured as the proportion of total debt (dlc+dltt) that is due within three years (dlc+dd2+dd3). The higher this ratio, the larger proportion of maturing debt in the firm's outstanding liabilities and the shorter maturities that firm has.

Leverage: We measure leverage as the sum of long-term debt (dltt) and debt in current liabilities (dlc) divided by total assets (at).

Net Working Capital: We subtract cash (che) from net working capital (nwc), then divided total assets (at). This measure is net of cash.

Capital Expenditure: We measure capital expenditure as the ratio of capital expenditure (capex) to total assets (at).

R&D: R&D is measured as the ratio of R&D expense (xrd) to sales (sale). We replace all the missing R&D expense with zeros.

Dividend Dummy: The dividend dummy is defined as equal to one in years in which a firm pays a dividend ($dv > 0$) and equal to zero otherwise.

Acquisitions: Acquisition is measured as acquisition expenditures (aqc) divided by total assets (at).

Issuance: Issuance measures the issuance of short- (dlcch) and long-term (dltis) debt net of the reduction of long-term debt (dltr) in any given year. We include net debt issuance as a control variable because the "cash is negative cash" argument.

Tangibility: Tangibility is the ratio of net property, plant and equipment (ppent) to the total assets (at).

Abnormal Earnings: Abnormal earnings is measured as the difference between earning before interest, taxes, depreciation, and amortization (EBITDA) in year t and t+1, divided by the share price in year t.

Asset Maturity: Following Stohs and Mauer (1996) and Johnson (2003), the average asset maturity is measured as the value-weighted maturity of long- and short-term assets, where the maturity of long-term asset is calculated as gross property, plant, and equipment (ppegt) divided by depreciation expense (dp) and the maturity of short-term asset is calculated as current assets (act) over costs of goods sold (cogs).

Term spread: We measure monthly term spread by the difference between the month-end yields on a 6-month treasury bill and a 10-year constant maturity treasury bond. The term spread is matched to the month of a firm's fiscal year-end.

Rating dummy: A rating dummy is assigned a value of 1 if a firm has a long-term debt rating at that year, and 0 otherwise.

4.2 SUMMARY STATISTICS Table 1 displays descriptive statistics of the variables used in the regressions. The average cash holdings is 16%, suggesting the existence of some financial frictions that lead firms to reserve excess cash for hedging motive, otherwise cash is just negative debt and firms should be able to raise any amount of cash whenever they need it. An average firm's outstanding debt maturity portfolio consists of 51% short-term debt, i.e. debt maturing within the next three years. Moreover, notice that both the cash ratio and the proportion of short-term debt vary considerably across firms with a standard deviation of 19% and 27% respectively.

We breakdown the average and median of cash ratio and maturity structure into annual level and present these statistics in table 2. Column 1 shows that average of cash increase from 12.9% in 1992 to 16.6% in 2006. The median of the cash ratio shares the same trend as the average. This upward trend of cash holdings is consistent with Bates et al. (2009) in which they attribute this increase to the raised volatility of firm's cash flows. We agree with them on the important role that cash flow uncertainty played for hoarding cash. Moreover, as we highlight in the last two columns of table 2, firm's maturity structure also lengthes substantially as the average proportion of short-term debt outstanding drops from 55.0% to 48.2% during the same sample period. Hence, we argue that the hedging motive against future roll-over risk also plays a role in explaining firm's cash hoarding decisions.

Figure 1 illustrates the average cash ratios and leverage ratios across the firm debt maturity quintile over the sample period. The debt maturity is measured as the proportion of total debt maturing within the next three years, so the first quintile indicates the long-end of the maturity structure while the fifth quintile represents the short-end. The blue curve is the average cash ratios which displays a "U" shape relationship with respect to the debt maturity and the red curve is the leverage ratio which is monotonically decreasing as the maturity goes short. These data patterns are consistent with our model predictions. Next we will formally test these predictions in a regression setting.

5 Joint Determinants of Cash Holdings, Leverage and Maturity

5.1 Ex-ante determinants of cash holdings In this section, we investigate the ex-ante relationship between cash holdings and debt maturity structure. We first present baseline multivariate panel regression results that does not consider the possible endogeneity problem associated with cash holdings, leverage and debt maturity. Next we estimate jointly the cash holdings and debt maturity in a simultaneous equations model in which we take into account the endogeneity problem. Finally we use instrumental variable to estimate the effect of maturity on leverage.

Table 3 reports baseline single equation regressions predicting cash reserves level in the prior 2007 crisis period. All the standard errors are robust to clustering by firm. After imposing the data restrictions described in section 4.1 and excluding observations with missing values, the final panel consists of 31,353 firm-year observations for 3,594 unique firms. The dependent variable is firm's cash-to-assets ratio. R^2 is within group for fixed effects models.

The first column reports estimates from OLS regression. All of the coefficients are significant at 10% level and consistent with the regression results in Bates et al. (2009). Cash holdings is positively related to Tobin's Q which indicates that firms accumulate more cash to seize more profitable investment opportunities. Coefficient of R&D expenses is positive as well since these high R&D firms face higher cost of financial distress. On the other hand, cash holdings is negatively related to firm's size, leverage, net working capital, capital expenditure, dividend payoff and acquisition activities. Our results are also consistent with Opler et al. (1999) on the signs of these coefficients. They have a detailed section discussing the theories and implications of those coefficients. We will not rephrase their findings since they are not the focus of this paper. We add one more control variable, firm's net debt issuance, as in Bates et al. (2009). We expect higher cash inflow from debt issuance raises cash reserves and the positive estimated coefficient is consistent with our argument.

The estimate of coefficient for maturity is 0.020 and significant, but then switches sign if we control for firm fixed effects. The coefficient becomes -0.015 in the second column when we control for firm fixed effects. This estimate is both statistically and economically significant which indicates that for firms with one less percent total debt maturing within next three years, ceteris paribus, their cash holdings increases by 1.5%.

This result is robust when we include both firm and year fixed effects as reported in column 3. All the other estimates remain their qualitative influence on cash holdings. In the last column, we add square of proportion of short-term debt into the regression. The coefficient on this square term is positive and on the first order term is negative, both significant at 1% level. This result supports our hypothesis that the outstanding debt maturity has a "U" shape effect on firm's saving decisions. Facing roll-over risk, when the debt maturity is concentrated in the short-end, firms choose to hold more cash out of internal funds to help repaying maturing debt. When the debt maturity is in the long-end, firms reserve more cash from their borrowing to capture more investment opportunities in period of financing difficulty.

5.2 ENDOGENEITY PROBLEM Firms' cash holdings, leverage and debt maturity are likely to be jointly determined. To correct the potential endogeneity problem exists in our regression specification in last section 5.1, we use simultaneous equations models to account for the joint decisions on cash holdings, leverage and debt maturity. Following our specification in the section 5.1, the cash holdings equation includes Tobin's Q, firm size, cash flow, net working capital, capital expenditure, R&D expense, dividend dummy, acquisition expense, leverage, net debt issuance as exogenous variables. In particular, we add the squared term of debt maturity in this equation to test whether these is a nonlinear relationship exists between cash holdings and debt maturity. In the leverage equation and maturity equation, we follow Johnson (2003) and Billett et al. (2007) to include size, Tobin's Q, cash flow, tangibility, cash flow volatility and investment tax credit dummy in the leverage equation. Firm size, Tobin's Q, net debt issuance, squared firm size, cash flow volatility, asset maturity, debt rating dummy, term spread and investment tax credit are specified as independent variables in the maturity equation. We estimate the system of equations by generalized method of moments (GMM) to account for the potential nonlinearity in the explanatory variables.

Table 4 presents the estimates from the systems of equations. The first column displays estimation results from cash holdings equation. Consistent with our hypothesis, the effect of maturity has on cash holdings first declines at a decreasing speed and then rises, i.e. a "U" shape patten. Hence, the empirical evidence exhibits more cash holdings is associated with either extremely short or long debt maturity. Most of the other estimates have the same sign as in Bates et al. (2009) and Harford et al. (2014).

Another prediction our model makes is that firms with shorter debt maturity will optimally choose borrow less to hedge against roll-over risk, so we expect a negative relationship between proportion of short-term debt and leverage. Notice that this is different from the liquidity risk effect argued in Diamond (1991). Here firms find borrow short-term and save cash out of borrowing cannot effectively mitigate the refinancing risk, so they will not borrow ex-ante.

As expected, the third column of table 4 shows the estimated coefficients of leverage equation. Note that GMM estimation still require instrument variables to identify the system of equations. A widely used instrument in the literature for debt maturity is asset maturity, such as in Stohs and Mauer (1996), Johnson (2003) and Billett et al. (2007). In addition, we use debt rating dummy and term spread to help identification. We expect firms with a long-term debt rating will borrow in longer term and the term spread is negatively related to debt maturity. The results shown in the last column confirm our predictions and other coefficients are largely consistent with Johnson (2003) and Billett et al. (2007).

5.3 Ex-post differences of firm's decisions We examine the financial and real effects of firm's ex-ante heterogeneity in debt maturity during the 2007 credit crisis in this section. The full 1992-2012 panel data after imposing restrictions outlined in section 4.1 left with 54,520 firm-year observations and 5,043 unique firms. We then split this sample into three subgroups, two treatment groups and a control group, based on firms' ex-ante debt maturity structures. We use cross-sectional observations in 2006, one year prior to the 2007 crisis, as a cutoff date to assign groups. Almeida et al. (2009) collects quarterly data from COMPUSTAT, so they are able to employ a finer cutoff date for the crisis. Nevertheless, I obtain similar results to theirs in the ex-post effects on firm's investment decisions. Firms with ex-ante fewer maturing debt invest more ex-post compared to the control group, effectively mitigating the roll-over risk, while firms with ex-ante more maturing debt also hold more cash, however this does not lead to a higher level of investment ex-post for those firms.

Our criteria to assign treatment groups is the following: If a firm has a maturity ratio, i.e. proportion of total debt maturing within next three years, that is within the bottom one quintile in cross-sectional sample, then we classify this firm as a member in treatment group concentrating in the long-end of debt maturity structure. If a firm's debt maturity is within the top one quintile, we assign this firm as a member in a different treatment group concentrating in the short-end of maturity structure. The bottom and top quintile cutoff is a arbitrary number we pick up to initialize our test and it will be altered in the section 6 for robustness check. Then we create two treatment dummy variables that equals 1 if the observation is from the treatment group in the long-end and 0 otherwise. The other dummy equals 1 if the observation is from the treatment group in the short-end and 0 otherwise.

Then we regress outcome variables against a set of control variables, the treatment dummies, the time dummy and the interaction of treatment dummies and time dummy. The coefficient in front the interaction term of treatment dummy and time dummy captures the difference between treatment and control group before and after the 2007 crisis, i.e. difference-in-difference. The panel regression can be written in the following way:

$$Y_{i,t} = \alpha + \beta_1 X_{i,t} + \beta_2 D + \beta_2 T_t + \gamma D * T_t + \varepsilon_{i,t}, \tag{5.1}$$

where $Y_{i,t}$ is the outcome variable; α is a constant; $X_{i,t}$ is the set of control variables; T_t is the time dummy; D is the treatment dummy and γ is the diff-in-diff estimator.

Table 5 shows the regression results for the firm investment model. All regressions include year dummies. The standard errors are corrected on the basis of clustering by firms. Our model predicts that when firms experience roll-over difficulties, firms that accumulate more cash ex-ante because of longer debt maturity will have more flexibility to finance valuable investment opportunities while the firms in the short-end of maturity structure will not. Therefore, we expect the coefficient of the long-end treatment dummy to be positive when the dependent variable is investment and negative or insignificant for the short-end treatment dummy.

The table demonstrates the estimates when outcome variable is investment. We measure investment as the ratio of capital expenditure (capex) over total assets (at). The coefficient of long-end treatment dummy is positive and significant. Almeida et al. (2009) employs a matching strategy to explore the effects of ex-ante heterogeneity of debt maturity structure on firm's investment decisions. They argue that by matching the firms with similar characteristics except variations in maturity structures, after the 2007 financial crisis, firms with shorter maturities reduce more on investments. Our findings are consistent with theirs. In addition, we include a treatment dummy for firms concentrating on short-term debt in their liabilities. Although those firms also hold more cash as shown in table 4, they lack the flexibility to finance their investment projects when a negative credit shock hits the economy. Consequently the coefficient of short-end treatment dummy is insignificant and negative which indicates those cash holdings do not give firms with more short-term debt a flexibility to finance investment.

6 Robustness Check

6.1 Alternative Maturity Cutoff This section perform some additional tests to ensure that our estimation results are robust and consistent. We alter the debt maturity cutoff value to show that our results cannot be attributed to different treatment group assignments. Table 6 summarizes these treatment effects under various treatment group assignments. Altering the cutoff criteria does not change our results qualitatively. Across these three specifications, firms with longer ex-ante debt maturity structure significantly draw down more on their cash holdings and has a higher level of investment compared to control group firms when a credit shortage shock hits the economy.

6.2 Placebo Years The exogenous economy-wide credit supply contraction in 2007 provides an relatively clean event for our identification strategy outlined above. Therefore, if the financial crisis in 2007 identifies the causal relationship between investment and debt maturities, then we should not find similar significant behavior differences between treatment and control group during other non-crisis period. To support that argument, we perform placebo tests across years prior to 2007. To conduct the placebo tests, we replicate the same diff-in-diff test as in table 5, but with non-crisis periods from 2000 to 2006. More specifically, we assign firms into treatment and control group by their one-year prior debt maturity structure status as if there were credit contractions in each of those placebo years.

Table 7 reports the results of these placebo tests for six sub-periods. Across the six placebo sub-periods, the treatment effect changes dramatically that confirms our identified causal relationship between debt maturities and investment. Most of the coefficients of long-end treatment on investment become insignificant which indicates almost no differences of firm policies between long-end treatment and control groups detected in those periods. Several treatment coefficients are significant, such as in 2003-2004, 2001-2002, but the coefficient is negative which means long-end treatment firms reduce more of their capital investment in these years instead of raising them. This suggests that the endogeneity problem, if any, we may have as a general structure in the data is biasing us away from the main results in table 5.

7 Conclusion

In this paper, we propose a model that determines the firm's liquidity management, investment decisions and debt maturity structure. We find a "U" shape relationship between cash holdings and debt maturity such that the marginal benefit of accumulating cash is the highest at the short- and long-end of the maturity structure. This is because in the presence of rollover risk, firms with a higher proportion of short-term debt hold more cash to repay their maturity liabilities, and firms with longer debt maturity accumulate cash to mitigate the underinvestment problem. However, the cash reserves come from different sources depending on the outstanding debt maturity structure.

We empirically test our hypotheses. First, firms' cash holdings are nonlinearly related to its outstanding debt maturity structure before credit falls short. Second, firms with longer maturity structures ex-ante should have more flexibility on their internal funds to invest than their peers with shorter maturity structures during a period of credit dry up. We evaluate these model predictions using a sample of firms from COMPUSTAT over a twenty years time span including the 2007 sub-prime crisis. After taking into account the joint determination of cash holdings and debt maturity, we find a significant "U" shape relationship between cash holdings and debt maturity structure, and debt maturity is positively related to leverage. In addition, by carefully designing a difference-in-difference approach, our regression results indicate that after the negative credit supply shock, firms with ex-ante longer maturity structure significantly reduce their cash holdings, increase their investment compared to firms with shorter ex-ante maturity structure. Placebo tests confirm that debt maturity has real effects, and cash reserves mitigate rollover risk.

A Proof of Proposition 1

By assumption $r_b > r_a \geq 0$, then $(\frac{1+r_a}{1+r_b} - 1) < 0$. As average maturities shorten, δ goes up, $\frac{1}{1-\delta}$ goes up, and the denominator of equation (3.12) decreases. This increases $f'(I_1)$. Because we assume the production function $f(\cdot)$ is a concave function, investment I_1 must decline for $f'(I_1)$ to rise.

Combine constraints (3.6) and (3.7) to get $I_1 = b_0(q_0(1 + r_a) - 1)$. Since the prices q_0 and r_a are exogenously given, if I_1 decreases, then b_0 decreases as well. Use the constraint that $a = q_0 b_0$, cash holding a must drop as δ goes up.

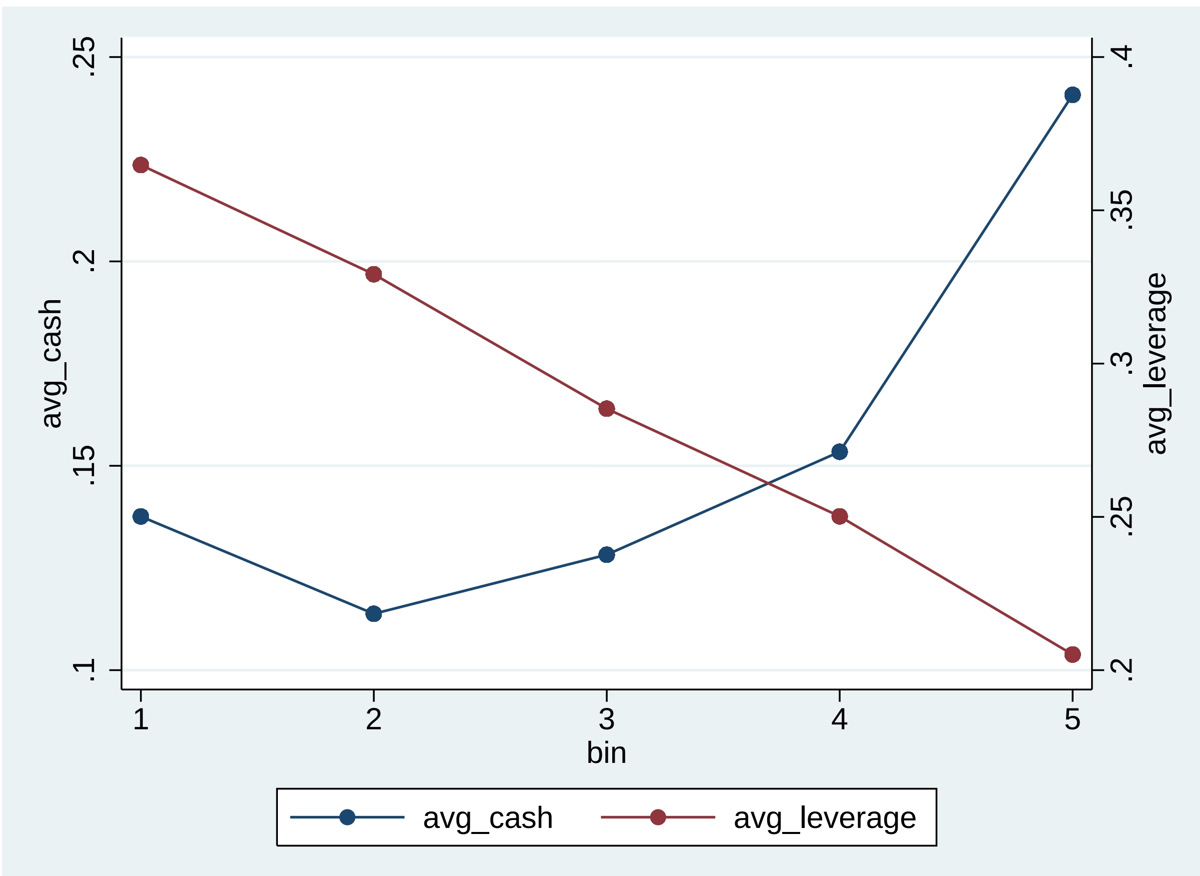

Figure 1: Average Cash Holdings and Leverage Ratio accross Firm Debt Maturity from 1992 to 2012

Table 1: Summary statistics for the COMPUSTAT annual sample 1992-2012

Variable	Mean	Std Dev.	25th percentile	Median	75th percentile
Cash	0.16	0.19	0.03	0.08	0.21
Q	2.39	3.05	1.12	1.51	2.34
Size	1.21	2.63	-0.65	1.35	3.06
Cashflow	0.05	0.41	0.06	0.14	0.21
Leverage	0.29	0.24	0.10	0.24	0.40
NWC	-0.01	0.40	-0.07	0.03	0.16
Capex	0.06	0.07	0.02	0.04	0.08
R&D	0.27	1.38	0.00	0.00	0.05
Dividend	0.39	0.49	0.00	0.00	1.00
Acquisition	0.02	0.06	0.00	0.00	0.01
Maturity (Prop. short)	0.51	0.38	0.15	0.47	0.96
Issuance	0.03	0.15	-0.03	-0.00	0.05
Tangibility	0.30	0.24	0.11	0.23	0.44
Asset Maturity	1.79	1.17	1.09	1.86	2.59

The panel data used in this table come from COMPUSTAT's North America Fundamentals Annual, firm-year observations from fiscal year 1992 to 2012. This entire sample contains 117,799 firm-year observations for 9,674 unique firms. Firms from financial institutions (SIC codes 6000-6999), utilities (SIC codes 4900-4999) not-for-profit organizations, and governmental enterprises (SIC cods greater than 8000) are excluded. Cash is defined as the ratio of cash and short-term investments to total assets. Net cash is the ratio of cash and short-term investments net of debt in current liability to total assets. Q is defined as the ratio of total assets plus market capitalization minus common equity to total assets. Size is measured as log of total assets in 2005 dollars. Cash flow is measured as the ratio of income before extraordinary items plus depreciation and amortization to total assets. Maturity structure is measured as the proportion of total debt that is due within three years. Leverage is the sum of long-term debt and debt in current liabilities divided by total assets. Net working capital is calculated as net working capital minus cash, then divided total assets. Capital expenditure is the ratio of capital expenditure to total assets. R&D is measured as the ratio of R&D expense to sales. The dividend dummy is defined as equal to one in years in which a firm pays a dividend and equal to zero otherwise. Acquisition is measured as acquisition expenditures divided by total assets. Issuance measures the issuance of short- and long-term debt net of the reduction of long-term debt in any given year. Firm's market value is measured as the sum of the market value of equity, the bookvalue of both short- and long-term debt, deflated to 2005 dollars.

Table 2: Average and Median Cash and Maturity Structure

Year	Avg. Cash	Med. Cash	Avg. Maturity	Med. Maturity
1992	0.128	0.067	0.550	0.531
1993	0.135	0.068	0.547	0.535
1994	0.120	0.061	0.542	0.525
1995	0.134	0.058	0.540	0.522
1996	0.146	0.067	0.524	0.479
1997	0.149	0.068	0.497	0.441
1998	0.143	0.062	0.497	0.446
1999	0.149	0.061	0.509	0.466
2000	0.149	0.058	0.528	0.513
2001	0.149	0.067	0.527	0.506
2002	0.148	0.073	0.531	0.499
2003	0.160	0.087	0.512	0.470
2004	0.169	0.097	0.509	0.457
2005	0.169	0.091	0.493	0.436
2006	0.166	0.087	0.482	0.411
2007	0.163	0.083	0.485	0.419
2008	0.151	0.084	0.521	0.484
2009	0.172	0.109	0.542	0.520
2010	0.173	0.110	0.527	0.494
2011	0.165	0.096	0.496	0.424
2012	0.160	0.097	0.466	0.364

The sample includes firm-year observations from fiscal year 1992 to 2012. The sample contains 117,799 firm-year observations for 9,674 unique firms. Firms from financial institutions (SIC codes 6000-6999), utilities (SIC codes 4900-4999) not-for-profit organizations, and governmental enterprises (SIC cods greater than 8000) are excluded. Cash is defined as the ratio of cash and short-term investments to total assets. Maturity is measured as the proportion of total debt matures within next three years.

Table 3: Single Equation Determinants of Cash Holdings

Dependent Variable	Cash			
Model	OLS	Firm FE	Firm&Year FE	Firm&Year FE
Q	0.001***	0.001***	0.001**	0.001*
	(0.000)	(0.008)	(0.010)	(0.010)
Size	-0.003***	-0.006***	-0.005**	-0.005**
	(0.000)	(0.007)	(0.034)	(0.035)
Cashflow	-0.009*	0.016**	0.015**	0.015**
	(0.090)	(0.026)	(0.036)	(0.031)
Leverage	-0.179***	-0.105***	-0.103***	-0.104***
	(0.000)	(0.000)	(0.000)	(0.000)
NWC	-0.089***	-0.050***	-0.049***	-0.050***
	(0.000)	(0.000)	(0.000)	(0.000)
Capex	-0.241***	-0.134***	-0.128***	-0.128***
	(0.000)	(0.000)	(0.000)	(0.000)
R&D	0.048***	0.012***	0.012***	0.012***
	(0.000)	(0.000)	(0.000)	(0.000)
Dividend	-0.063***	0.009***	0.008**	0.008**
	(0.000)	(0.006)	(0.017)	(0.013)
Acquisition	-0.275***	-0.196***	-0.195***	-0.194***
	(0.000)	(0.000)	(0.000)	(0.000)
Issuance	0.066***	0.047***	0.046***	0.045***
	(0.000)	(0.000)	(0.000)	(0.000)
Maturity (prop. short)	0.020***	-0.015***	-0.013***	-0.096***
	(0.000)	(0.000)	(0.000)	(0.000)
$Maturity^2$				0.072***
				(0.000)
Constant	0.231***	0.205***	0.213***	0.227***
	(0.000)	(0.000)	(0.000)	(0.000)
Year Dummies	No	No	Yes	Yes
R-squared	0.283	0.054	0.058	0.061
N. of observations	31353	31353	31353	31353

The panel data used in this table come from COMPUSTAT's North America Fundamentals Annual, firm-year observations from fiscal year 1992 to 2006. This prior 2007 crisis period sample contains 117,799 firm-year observations for 9,674 unique firms. Firms from financial institutions (SIC codes 6000-6999), utilities (SIC codes 4900-4999) not-for-profit organizations, and governmental enterprises (SIC cods greater than 8000) are excluded. Cash holdings is defined as the ratio of cash and short-term investments to total assets. Q is defined as the ratio of total assets plus market capitalization minus common equity to total assets. Size is measured as log of total assets in 2005 dollars. Cash flow is measured as the ratio of income before extraordinary items plus depreciation and amortization to total assets. Maturity is measured as the proportion of total debt that matures within next three years. Leverage is the sum of long-term debt and debt in current liabilities divided by total assets. Net working capital is calculated as net working capital minus cash, then divided total assets. Capital expenditure is the ratio of capital expenditure to total assets. R&D is measured as the ratio of R&D expense to sales. The dividend dummy is defined as equal to one in years in which a firm pays a dividend and equal to zero otherwise. Acquisition is measured as acquisition expenditures divided by total assets. Issuance measures the issuance of short- and long-term debt net of the reduction of long-term debt in any given year. The dependent variable is cash-to-assets. All standard errors are clustered by firms. The R^2 is within group for fixed effects regression. *,** and *** denotes significance level at 10%, 5% and 1% respectively.

Table 4: Joint Determinants of Cash Holdings, Leverage and Maturity

	Three-Equation System		
Depedent Variable	Cash	Maturity	Leverage
Constant	0.525***	0.571***	0.528***
	(0.000)	(0.000)	(0.000)
Cash		0.497***	-0.175***
		(0.000)	(0.000)
Maturity (prop. short)	-2.524***		-0.479***
	(0.000)		(0.000)
Maturity^2	2.576***		
	(0.000)		
Leverage	-0.509**	-0.194***	
	(0.011)	(0.000)	
Size	0.023***	-0.055***	-0.014***
	(0.004)	(0.000)	(0.000)
Q	0.004*	-0.012***	-0.003*
	(0.074)	(0.000)	(0.051)
Cashflow	0.043***		-0.163***
	(0.001)		(0.000)
NWC	-0.209***		
	(0.002)		
Capex	-0.309***		
	(0.001)		
R&D	0.043***		
	(0.000)		
Dividend	0.006		
	(0.587)		
Acquisition	-0.272***		
	(0.000)		
Issuance	0.182***	-0.279***	
	(0.001)	(0.000)	
Size^2		0.009***	
		(0.000)	
Tangibility			0.051***
			(0.001)
Cashflow Volatility		-0.022	0.196***
		(0.382)	(0.000)
Asset Maturity		-0.000***	
		(0.000)	
Debt rating dummy		-0.163***	
		(0.000)	
Term spread		0.006***	
		(0.000)	
Investment tax credit dummy		-0.023*	-0.036***
		(0.086)	(0.000)

The sample covers COMPUSTAT firms over the 1992-2006 period. The estimation is performed using simultaneous equations model. For the maturity equation, the explanatory variables are firm size, leverage, asset maturity, debt rating dummy, term spread, net debt issuance and year dummies. In the cash holding equation, we include Tobin's Q, firm size, cash flow, net working capital, capital expenditure, R&D expense, dividend dummy, acquisition expense, leverage, net debt issuance and year dummies. The estimates for maturity equation are not tabulated. All standard errors are robust and clustered by firms. *,** and *** denotes significance level at 10%, 5% and 1% respectively.

Table 5: Ex-post Real Effects

Dependent Variable	Investment
Leverage	0.014***
	(0.000)
Maturity (prop. short)	-0.012***
	(0.000)
Size	-0.000
	(0.846)
Q	0.003***
	(0.000)
Cashflow	0.020***
	(0.000)
Bottom quintile of maturity (long-end)	0.007*
	(0.058)
Top quintile of maturity (short-end)	-0.002
	(0.676)
N. of observations	47678

The simultaneous equations on investment, leverage and debt maturity is estimated by maximum likelihood (ML) method where maturity is instrumented by rating dummy and term spread and leverage is instrumented by tangibility and investment tax credit. All standard errors are robust and clustered by firms. *,** and *** denotes significance level at 10%, 5% and 1% respectively.

Table 6: Different Treatment Group Assignments

Treatment effects	Bottom 20% Maturity	Bottom 15% Maturity	Bottom 10% Maturity
Long-end	0.007*	0.008*	0.016***
	(0.058)	(0.069)	(0.005)
Short-end	-0.002	-0.002	-0.001
	(0.676)	(0.622)	(0.719)

This table summarizes treatment effect under various treatment group assignments. Long-end treatment dummy is defined as if a firm's maturity structure is within the bottom 20%, 15% or 10% of total sample in 2006, then 1 is assigned to that firm's observation in 2007 and 0 otherwise. Short-end treatment dummy is defined as if a firm's maturity structure is within the top 20% of total sample in 2006, then 1 is assigned to that firm's observation in 2007 and 0 otherwise. *,** and *** denotes significance level at 10%, 5% and 1% respectively.

Table 7: Placebo Tests

Long-end treatment effect	2005-2006	2004-2005	2003-2004	2002-2003	2001-2002	2000-2001
Investment	0.001	-0.002	-0.007**	-0.004	-0.006**	0.003
	(0.796)	(0.631)	(0.020)	(0.170)	(0.045)	(0.495)

This table summarizes placebo effects during non-crisis periods. Long-end treatment dummy is defined as if if a firm's maturity structure is within the bottom 20% of total sample in the year prior to the placebo crisis year, then 1 is assigned to that firm's observation in the placebo year. The number of placebo year cross-sectional firms are 2,953, 2,889, 2,833, 2,746, 2,718 and 2,687 respectively. *,** and *** denotes significance level at 10%, 5% and 1% respectively.

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