

New insights about the relationship between corporate cash holdings and interest rates

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Abstract Between 1970 and 2014 the federal funds rate soared from approximately 7.18 % to 16.38 %, and subsequently declined to 0.09 %. Based on economic theory, corporate cash holdings should have moved inversely with these interest rate swings. Using a new measure of cash holdings and a random effects threshold model, we examine this relationship over the past four and a half decades and show that the expected negative relationship does not exist. Furthermore, some established motives for cash holdings do not explain these results. Using a quantile regression, we show that a positive relationship between cash holdings and interest rates exists among all quantiles of cash holdings. All of these results imply that there is not one particular group of firms that is driving the positive relationship and a revised theory of the relationship between interest rates and cash holdings may be warranted.

Keywords Cash · Cash holdings · Interest rates · Federal funds rate

JEL Classification G30 · G32

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1 Introduction

Baumol (1952) and Tobin (1956) claimed that as interest rates fall corporations will hold more cash due to the lower opportunity cost. With interest rates at 40 year lows, it leaves one to wonder if this negative relationship has held over time. The primary contribution of this paper is that it is the first extensive empirical study of the relationship between interest rates and cash holdings in the United States. While theoretical relationships were proposed in the 1950's, they were not examined empirically. Rather than simply including a measure of interest as a control variable, it is the primary focus of this paper. In addition to empirically testing for the relationship between cash holdings and interest rates, the methodology and variables capturing cash holdings are distinguished from recent papers on corporate cash holdings.

The relationship between cash holdings and interest rates is tested using a random effects threshold model, which distinguishes the relationship over different ranges of interest rates. To emphasize why it is necessary to control for varying interest rates, Fig. 1 plots the federal funds rate from January 1970 until December 2014. During the 1970's, rates varied from 4.43 to 11.19 %. This is the only time during the sample where we see a uniform increase in rates. Rates reached a peak at 16.38 % in 1981 but subsequently declined to levels seen during the 1970's. In the 1990's, rates continued to decline, but at a slower pace than was experienced during the 1980's. Finally, during the 2000's and the most recent decade, rates have continued to decline even further to 0.09 % leaving interest rates at the lowest levels experienced over the last 40 years. Because of the variation in rates, the data are divided into interest rate ranges that are found by searching for thresholds in the interest rate series. This allows us to see if the negative relationship holds in the face of the dramatic fluctuation that interest rates experienced during these times.

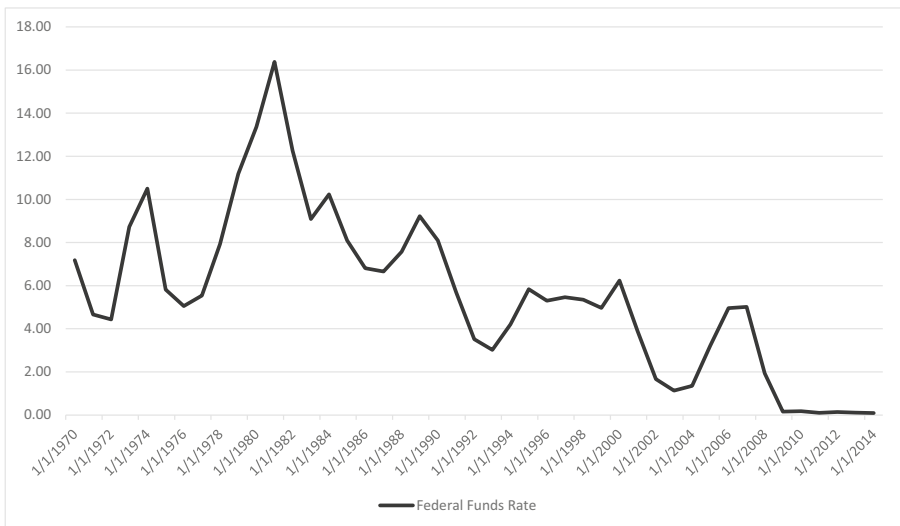
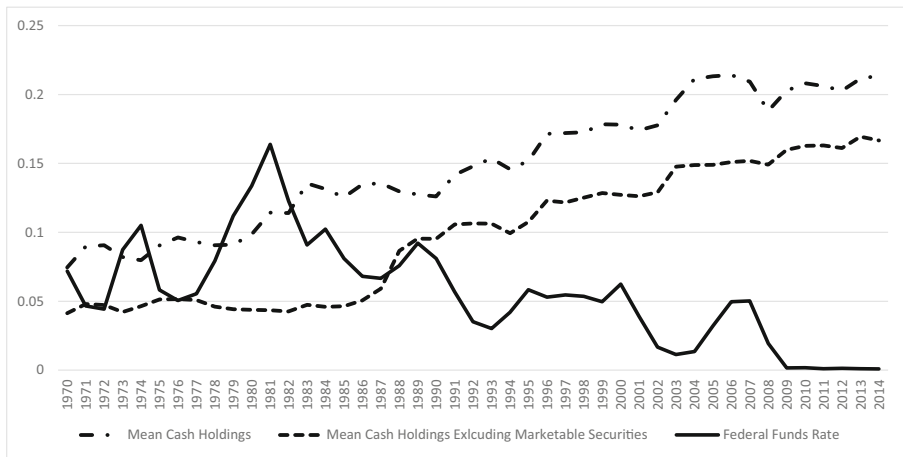


Fig. 1 One-year treasury constant maturity rate. Figure 1 plots the federal funds rate from 1970 to 2014. The data was obtained from the Federal Reserve Economic Data

While most previous papers have used cash and marketable securities divided by total assets as the main cash holdings variable, we use cash holdings excluding marketable securities divided by total assets (i.e. cash/total assets). The difference between these two variables lies with the marketable securities, which can lead to conflicting relationships between cash holdings and interest rates. Figure 2 plots the mean and median of cash holdings with and without marketable securities and the federal funds rate from January 1970 to December 2014. Panel A of Fig. 2 shows that using two different measures of the mean of cash holdings is vital to the study of the relationship between corporate cash holdings and interest rates. The mean of cash

a Mean Cash Measures



b Median Cash Measures

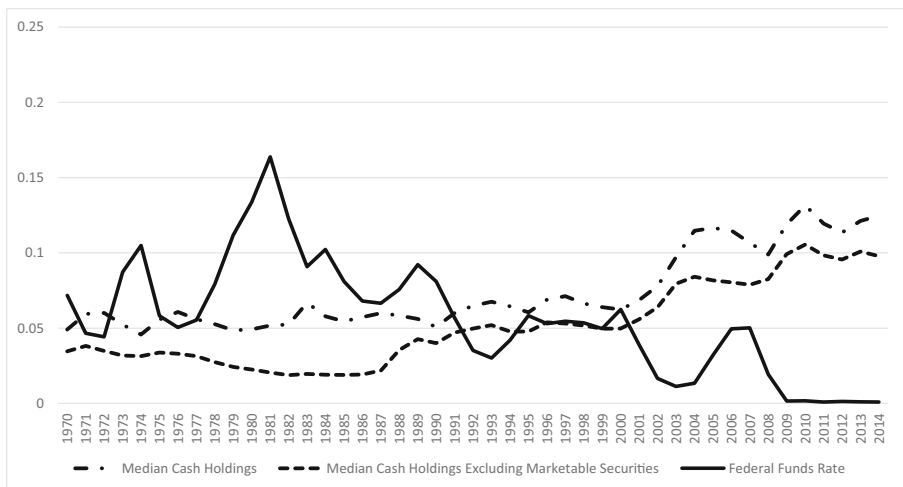


Fig. 2 Graph of cash holdings and the one-year treasury constant maturity rate. Figure 2 plots cash holdings, cash holdings excluding marketable securities, and the federal funds rate from January 1970 until December 2014. Both measures of cash holdings were created by taking the mean and median of Compustat data for all firms used in the paper. The federal funds rate obtained from the Federal Reserve Economic Data. All numbers are expressed as decimals

holdings is steadily increasing over time. Cash holdings without marketable securities shows a rather stable mean during the 1970's and early 1980's but has experienced various rates of increase since the late 1980's. In Panel B, the median measure shows that both cash holdings including and excluding marketable securities are relatively stable until the 1990's when each starts to increase. These dramatic differences over time highlight the need to empirically examine whether the negative relationship holds over time.

We document a non-negative relationship covering several ranges of interest rates, particularly rates since the 1990's. Thus, alternative explanations for the non-theorized relationship are tested. The additional tests are based on recent cash holdings papers and they include the tax-based explanation, pension fund contributions, zero-leverage firms, financially constrained and unconstrained firms, firm governance, and high-tech firms. None of these relationships, independently or together, fully explain the positive relationship. Finally, in an effort to find which firms are driving the relationship, quantile regressions are used, which allows for regressions based on different quantiles of the dependent variable and not the mean as is used in other models. In doing so, it is found that the positive relationship is driven not by a particular group of firms, but spans all groups. Thus, we conclude that the prior theorized relationship between cash holdings and interest rates may need to be adjusted to allow for the relationship that is documented.

The remainder of the paper is organized as follows: Section 2 discusses the relevant literature surrounding cash holdings and explores the hypothesis. Section 3 discuss the data and Section 4 presents the model. Section 5 presents the empirical results. Section 6 examines alternative explanations for the positive relationship discovered between interest rates and cash holdings. Section 7 presents results based on quantile regressions, and Section 8 summarizes our findings.

2 Literature review and hypothesis development

Given the recent attention paid to cash holdings and the extremely low interest rates, the relationship between interest rates and corporate cash holdings is of particular interest. However, it has received scant attention in the literature. One of the earliest papers to examine interest rates and cash is Baumol (1952), who showed that companies benefit by keeping cash on hand instead of borrowing cash or withdrawing it from an investment. Tobin (1956) expanded upon Baumol (1952) and showed theoretical evidence that the demand for cash will depend inversely on the rate of interest. He suggested that during times of high interest rates, companies will increase holdings of more liquid investments that earn higher rates and shift into cash only when a transaction must be made. Meltzer (1963) documented that changes in a firm's internal rate of return and interest rates are capable of explaining most of the observed changes in the velocity of business cash balances. Miller and Orr (1966) suggest that prior models apply reasonably well to households, but are less than satisfactory when applied to business firms. Their expansion of Baumol (1952), which allowed for stochastic cash flows leading to stochastic cash balances, suggested that cash balances fluctuate over time in both directions. However, the model still finds that cash balances will be a decreasing function of the interest rate.

In more recent literature, one of the most widely cited papers on cash holdings, Opler et al. (1999), used Keynes's (1936) "transactions-motive" for holding cash. This

motive suggests that liquid assets decrease with interest rates and the slope of the term structure. However, empirical tests did not include interest rates as an explanatory variable. Ferreira et al. (2005) looked at business conditions as a determinant of firms' cash holdings. They found evidence that cash levels increase during recessions, especially for financially constrained firms. Using the term spread and the 1-month Treasury bill (T-Bill) rate as two of five proxies for recessions, they documented that the term spread cannot explain cash holdings but that the 1-month T-Bill rate is a significant determinant of cash holdings.¹ Garcia-Teruel and Martinez-Solano (2008) documented a relationship between interest rates measured as the 1-year T-Bill rate, and cash holdings of small to medium sized firms in Spain from 1996 to 2001. They found that when interest rates were at their lowest, cash holdings reached its highest and vice versa. In the empirical tests, they found a negative relationship between cash holdings and the 1-year T-Bill rate. Bates et al. (2009) used the 3-month T-Bill rate and found a negative relationship between the log of the cash to total assets ratio and the interest rate. However, they were unable to verify a statistically significant relationship between their second measure for cash holdings, cash and marketable securities to total assets, and the T-Bill rate. Lins et al. (2010) surveyed Chief Financial Officers (CFOs) in twenty-nine countries to measure corporate liquidity around the world. The survey questioned CFOs about the importance they placed on the difference between the interest rate on debt and the interest rate on cash. Thirty-five percent of responding CFOs rated the difference as highly important, demonstrating that CFOs take interest rates into account when deciding to hold cash.

One would expect that based on prior theory corporate cash holdings would have a negative relationship with interest rates. In other words, as interest rates fall, the opportunity cost of holding money in investments falls and corporate cash holdings would increase and vice versa. However, we expand this to include all ranges of interest rates as prior literature did not discuss rates which the theories would or would not hold. This leads to our hypothesis:

Hypothesis The relationship between short-term interest rates (measured by the federal funds rate and 1-year Treasury Constant Maturity Rate) and corporate cash holdings should be negative and persist for all periods.

3 Data

The data set consists of all firms with non-missing observations in the Compustat Annual files data base from January 1970 until December 2014. Financial firms (SIC 6000–6999) and utilities (SIC 4900–4999) are excluded because cash is held for business practices and regulatory purposes, respectively. The sample is restricted to firms headquartered in the United States and firms with complete data for cash and marketable securities and cash and cash equivalents.² All corporate variables are

¹ Ferreira et al. (2005) define the term spread as the difference between the long term yield on government bonds and the one-year T-bill rate.

² In addition, all firms are required to have positive Total Assets and Sales. More than one year of data is required for all firms after all variables have been calculated.

winsorized at the lower and upper 1 % level. The data set contains 171,146 firm-year observations of more than 17,000 companies.

The main variable of interest capturing corporate liquidity is *cash holdings*. The most common variable used to measure cash holdings is defined as cash, cash equivalents, and marketable securities divided by total assets. For the purposes of this paper, *cash holdings* is defined as cash and cash equivalents divided by total assets.³ Cash and cash equivalents are defined by Compustat as “any immediately negotiable medium of exchange or any instruments normally accepted by banks for deposit and immediate credit to a customer’s account.”⁴ Excluding marketable securities ensures we are measuring the cash and cash equivalent holdings that a firm has on hand and not its short term investments. This is important to distinguish because the relationship between short term investments and interest rates will also be picked up in the regressions and can lead to conflicting results. As market rates of interest decline, companies might move money from short-term interest-earning investments into cash due to the lower opportunity cost and lower returns. This positive relationship between the short-term investments and interest rates might overpower the relationship between cash and cash equivalents and interest rates. Because of the conflicting relationships, we focus on results using the dependent variable excluding marketable securities.

The corporate control variables that have been chosen are in line with past literature such as in Opler et al. (1999). We control for a firm’s market-to-book rating, cash flow, net working capital-to-assets, capital expenditure-to-assets, leverage, R&D-to-sales, acquisitions-to-assets, dividends, investment grade rating, firm size, and the standard deviation of cash flows.⁵ All variables are defined in appendix Table 9. In addition to the corporate controls, we also include the federal funds rate. The federal funds rate is chosen because it is a benchmark for other interest rates and is an accurate reflection of short-term rates in which companies might can invest cash and cash equivalents.⁶ The federal funds rate is obtained from the Federal Reserve Economic Data (FRED).

Panel A of Table 1 presents the summary statistics for the variables just described. The summary statistics for *cash holdings including marketable securities* and *cash holdings* are discussed first because it is important to note the difference between the two variables. *Cash holdings including marketable securities* is larger than *cash holdings* as expected because of the short term investments, which is a significant component of liquid investments for most companies. The mean amount for cash holdings including marketable securities is 15.20 % as compared to the mean of cash holdings which is 10.19 %. 26 % of company-year observations pay a dividend each year and 6 % of company-year observations have an investment grade rating. On average, companies hold 30 % of total assets as debt. In the final row of Panel A, it is shown that the mean of the federal funds rate is 5.56 %.

³ In unreported regressions, the dependent variable in the baseline regressions are replaced with the ratio of cash and cash equivalent to net assets, where net assets excluded cash and cash equivalents. The results remain the same and are available upon request.

⁴ To be more specific, cash includes a bank or finance company’s receivables, bank drafts, banker’s acceptances, cash on hand (including foreign currency), certificates of deposit included in cash by the company, check (cashier’s or certified), demand certificates of deposit, demand deposits, letters of credit, and money orders.

⁵ We are aware that bond rating data is comprehensively collected by Compustat starting in 1985. The main results do not change when this variable is excluded. The results are available upon request.

⁶ In addition to the Federal funds rate the one-year Treasury constant Maturity Rate is tested. The results do not differ significantly from results presented.

Table 1 Summary statistics

<i>Panel A: Statistics on Corporate Variables and Interest Rates</i>						
Variable	Mean	Standard Deviation	Minimum	Maximum	Number of Observations	
Cash Holdings Including Marketable Securities	0.15204	0.19683	0	0.88170	194,208	
Cash Holdings	0.10191	0.14700	0	0.76104	194,208	
Market-to-Book	2.07173	2.91495	0.20163	22.38037	194,208	
Cash Flow	-0.06486	0.48036	-3.42296	0.29969	194,208	
Net Working Capital-to-Assets	0.02367	0.49485	-3.49688	0.57749	194,208	
Capital Expenditures-to-Assets	0.06824	0.07673	0	0.42823	194,208	
Leverage	0.30926	0.36039	0	2.47208	194,208	
R&D-to-Sales	0.20270	1.04251	0	8.92593	194,208	
Acquisitions-to-Assets	0.01628	0.05297	-0.00197	0.33835	194,208	
Dividend Dummy	0.25825	0.43768	0	1	194,208	
Investment Grade Dummy	0.05880	0.23526	0	1	194,208	
Size	13.13863	2.31218	7.56096	18.64068	194,208	
Cash Flow Riskiness	0.78697	2.77611	0.00175	224.84200	194,208	
Federal Funds Rate	5.5555	3.5483	0.09	16.38	-	
<i>Panel B: Threshold Test</i>						
Threshold	γ_1	γ_2	γ_3	SSR		
1 Threshold	5.30			299.1231		
2 Thresholds	5.30	9.22		228.3237		
3 Thresholds	1.93	4.43	7.57	154.3194		
<i>Panel C: Distribution of Observations in Each Region</i>						
Threshold	Range	Entire				
1 Threshold	Interest Rate < γ_1	0.4911				
	$\gamma_1 \leq$ Interest Rate	0.5089				

Table 1 (continued)

2	Thresholds	Interest Rate < γ_1	0.4911
		$\gamma_1 \leq$ Interest Rate < γ_2	0.3761
		$\gamma_2 \leq$ Interest Rate	0.1327
3	Thresholds	Interest Rate < γ_1	0.1941
		$\gamma_1 \leq$ Interest Rate < γ_2	0.1345
		$\gamma_2 \leq$ Interest Rate < γ_3	0.4260
		$\gamma_3 \leq$ Interest Rate	0.2455

This table represents the summary statistics on key variables for the 1970–2014 sample. *Cash holdings Including Marketable Securities* is defined as cash, cash equivalents, and marketable securities divided by total assets. *Cash holdings* is defined as cash and cash equivalents divided by total assets. *Market-to-book* ratio and is defined as the market value per share to the stated book value of equity. *Cash flow* is earnings after interest, dividends and taxes divided by total assets. *Net working capital-to-assets* is defined as working capital minus cash and marketable securities divided by total assets. *Capital expenditure-to-assets* is capital expenditure divided by total assets. *Leverage* is long term debt plus current debt divided by total assets. *R&D-to-Sales* is R&D divided by sales. *Acquisitions-to-Assets* are acquisitions divided by total assets. *Dividend Dummy* is 1 if the company pays a dividend and 0 otherwise. *Investment Grade Dummy* is set equal to 1 if a company has a bond grade of BBB- and above, otherwise the dummy equals zero. *Size* is the natural log of the firm's total assets in 2009 dollars. *Cash Flow Riskiness* is the measured as the standard deviation of industry cash flows computed by the manner suggested in Opler et al. (1999). It is calculated as the standard deviation of cash flows for the previous 20 years if available. Then the average is taken across the two-digit SIC code. *Federal Funds Rate* is the Federal Funds rate. The data displayed in Panel B are the thresholds for the model. The thresholds were found by minimizing the sum of squared residuals (SSR). The data displayed in Panel C are the distribution of observations that are in each region for each data set

4 Econometric model

To start, we use a random effects regression to examine the relationship between interest rates and cash holdings over the entire time period from 1970 until 2014. In Column 1 of Table 2, when including the interest rate in the model, we do find a negative and statistically significant relationship between *cash holdings* and the federal funds rate. While the negative relationship is statistically significant at a 1 % level, the economic significance is small. A one percentage point change in the interest rate represents a decline in the mean of *cash holdings* of 1.41 %.

However, Fig. 2 shows that while there is a general negative relationship between the two variables, this negative relationship might not hold within sub-periods because of the extreme variation in rates. We then use a random effects threshold model to test within sub-periods. The threshold model allows one to more closely examine the relationship between cash holdings and interest rates over time. The rationale behind using the model is that the relationship might behave differently when interest rates are within certain ranges.

In the model, the thresholds are based on the level of interest rates. They were found by searching for the threshold values by minimizing the sum of squared residuals (SSR) from the regression model that allows for a fixed number of mean-shifts in the level of interest rates. Models using one, two, and three thresholds are tested. In each model, the threshold is then used in indicator functions that split the data up into regions. Thus, the one threshold model divides the sample into two regions, the two threshold model into three regions, etc. Panel B of Table 1 details the thresholds for the federal funds rate. Each threshold value is identified as γ . γ_1 for the one threshold model is 5.30 % and is close to the mean federal funds rate. Panel C displays results for the percentage of the observations that lie in each indicator function’s region. Looking at Panel C, roughly 49 % of all observations in the data sets are below the threshold and the remainder are above. γ_1 and γ_2 for the two threshold model are 5.30 % and 9.22 %, respectively. While γ_1 is the same threshold value as γ_1 in our two threshold model, the additional threshold breaks up the upper interest rates into two regions. In Panel C, it is reported that roughly 49 % of the observations lie below γ_1 , 38 % of observations are between γ_1 and γ_2 , and the remaining observations are above γ_2 . The three thresholds in the final model are 1.92 %, 4.43 %, and 7.57 %. In Panel C, roughly 19 % of observations lie below γ_1 , 13 % are in the range between γ_1 and γ_2 , 43 % are between γ_2 and γ_3 , and the remainder are above γ_3 .

The interest rate, as well as the interaction between the interest rate and the threshold dummy, are included in all models. The model is detailed for the two threshold model in Eq. 1:

$$\begin{aligned}
 \text{cashholdings}_{it} = & \alpha_0 + \beta_1 \text{Interest Rate}_t + \beta_2 I(\text{Interest Rate}_t < \gamma_1) \\
 & + \beta_3 I(\gamma_1 \leq \text{Interest Rate}_t < \gamma_2) + \beta_4 (\text{Interest Rate}_t * I(\text{Interest Rate}_t < \gamma_1)) \quad (1) \\
 & + \beta_5 (\text{Interest Rate}_t * I(\gamma_1 \leq \text{Interest Rate}_t < \gamma_2)) + \gamma X_{it} + \varepsilon_{it}
 \end{aligned}$$

where X_{it} are the other control variables detailed in the data section. In all models, the indicator function for the highest interest rate region and the interaction between that region and the interest rate are omitted from the regression.

When estimating the marginal effect of the interest rate on cash holdings in a threshold model it is important to not focus solely on the coefficient on the interaction term. For

Table 2 Cash holdings and interest rates

	(1)	(2)	(3)	(4)
Federal Funds Rate	-0.00144*** (-16.54)			
Federal Funds Rate in Low Region		0.0005309 (0.41)	0.0162829*** (6.63)	0.0089619*** (4.65)
Federal Funds Rate in Middle Region			0.013533*** (4.72)	
Federal Funds Rate in Lower Middle Region				0.0026843 (0.57)
Federal Funds Rate in Upper Middle Region				0.0022909 (0.72)
Federal Funds Rate in High Region		-0.00134*** (-13.78)	-0.000258 (-1.52)	-0.000920*** (-7.26)
Market-to-Book	0.00501*** (17.85)	0.00502*** (17.87)	0.00502*** (17.86)	0.00499*** (17.75)
Cash Flow	0.0217*** (9.57)	0.0217*** (9.60)	0.0217*** (9.60)	0.0219*** (9.66)
Net Working Capital	-0.0242*** (-12.28)	-0.0241*** (-12.20)	-0.0241*** (-12.18)	-0.0241*** (-12.17)
Capital Expenditures to Assets	-0.185*** (-33.57)	-0.185*** (-33.39)	-0.185*** (-33.33)	-0.184*** (-33.32)
Leverage	-0.0563*** (-24.68)	-0.0562*** (-24.67)	-0.0562*** (-24.65)	-0.0563*** (-24.69)
R&D to Sales	0.00414*** (4.1)	0.00417*** (4.12)	0.00418*** (4.13)	0.00424*** (4.20)
Acquisitions to Assets	-0.188*** (-36.66)	-0.188*** (-36.36)	-0.188*** (-36.37)	-0.188*** (-36.34)
Dividend Dummy	-0.00117 (-1.41)	-0.00129 (-1.56)	-0.00121 (-1.46)	-0.00139* (-1.68)
Investment Grade Dummy	0.00267*** (2.73)	0.00277*** (2.84)	0.00244** (2.49)	0.00297*** (3.03)
Size	-0.00409*** (-8.03)	-0.00417*** (-8.12)	-0.00418*** (-8.14)	-0.00444*** (-8.59)
Cash Flow Riskiness	0.000509*** (4.59)	0.000497*** (4.50)	0.000492*** (4.44)	0.000518*** (4.68)
Lagged Cash Holdings	0.444*** (88.41)	0.444*** (88.39)	0.443*** (88.39)	0.444*** (88.43)
Constant	0.141*** (31.31)	0.139*** (29.91)	0.124*** (24.49)	0.131*** (27.12)
<i>N</i>	171146	171146	171146	171146
<i>Year Dummies</i>	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes

Table 2 (continued)

	(1)	(2)	(3)	(4)
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes
R ²	0.55	0.55	0.55	0.55

This table presents the empirical results from the random effects regressions of all firms for 1970–2014. *Cash holding* is the dependent variable in all regressions. All other variables are defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is *p* < .01

example, say we want to know the marginal effect of interest rates in the low threshold. The marginal effect of a change in *cash holdings* by a change in interest rate is given as:

$$\frac{\partial y}{\partial x} = \beta_1 + \beta_4 I(\text{Interest Rate}_t < \gamma_1) + \beta_5 I(\gamma_1 \leq \text{Interest Rate}_t < \gamma_2) \quad (2)$$

where *y* is *cash holdings* and *x* is the interest rate. If the interest rate was below γ_1 this would imply the effect was the linear combination of the coefficient on the interest rate and the interaction term, $\beta_1 + \beta_4$. Thus, the marginal effect when the interest rate is above γ_2 is just the coefficient on interest rate. For brevity, in all threshold regressions the conditional marginal effects are reported in the table.

In all models, standard errors are clustered at the firm level and industry dummies are included but are not reported.⁷ Year dummies were tested, but are omitted because including year dummies diminishes the effect of the across year variations of interest rates.⁸ One shortcoming of the random effects model is that it assumes that the unobserved heterogeneity is uncorrelated with the regressors. While this is unlikely, the Mundlak (1978) and Chamberlain (1980) means relaxes this assumption and allows one to control for the possible correlations between the unobserved heterogeneity and the regressors. Thus the Mundlak (1978) and Chamberlain (1980) means are included in the model. The means are simply the time average of each accounting variable across companies.⁹

In addition to the variables described in Section 3, we also include a lagged value of the dependent variable in the model. *Lagged cash holdings* is included in the model and is defined as cash holdings from the previous year.¹⁰ This is included due to the highly stable nature of cash holdings within firms.

5 Baseline threshold results and interpretations

The results for the relationship between cash holdings and interest rates using the one, two, and three threshold models are presented in Table 2. Column 2 reports the results for the one threshold model, column 3 for the two threshold model, and column 4 contains the results for the three threshold model.

⁷ Industry dummies are based on two-digit SIC code.

⁸ Results including year dummies are available upon request.

⁹ The time means for the Mundlak (1978) and Chamberlain (1980) devices are included in all models but, for brevity, their coefficients are not reported.

¹⁰ In unreported results, all baseline regressions are run excluding the lagged dependent variable. Results are similar and, in fact, strengthen and are available upon request.

The marginal effects for the relationship between the intervals of the federal funds rate and *cash holdings* are found at the top of the table. In column 2, the relationship between *cash holdings* and *interest rates in low region* is positive but not statistically significant from zero. The relationship between *interest rates in high region* and *cash holdings* is negative and statistically significant at a 1 % level. Thus, we do not find a negative relationship with low interest rates, but find no relationship at all. In column 3, the relationship between *cash holdings* and *interest rates in low region* is positive and statistically significant at a 1 % level. The relationship between *interest rates in middle region* and *cash holdings* is also positive and statistically significant at a 1 % level. The relationship in the high region is negative but not statistically different from zero. Once we include the additional threshold in the upper region, the results change from the two threshold model. In column 4, the relationship in the low region is positive and statistically significant at a 1 % level. The relationship between *cash holdings* and the interest rates in both middle regions are positive, but not statistically significant from zero. The relationship between *interest rates in high region* and *cash holdings* is negative and statistically significant at a 1 % level.

The statistically significant positive relationships are not as hypothesized by early economic theory. Not only is the relationship positive and statistically significant, it is also economically significant. In the two threshold model, a one percentage point change in federal funds rate during the low region increases *cash holdings* by 0.01628. While this does not seem like a large amount it represents a 15.97 % increase in the mean values of cash holdings (0.10191). A one percentage point change in the federal funds rate in the middle region increase *cash holdings* by 0.0135. This represents a 13.28 % increase in the mean value of cash holdings. In the three threshold model, a one percentage point increase in interest rates in the low region increases corporate cash holdings by 0.00896 or an 8.79 % increase in corporate cash holdings.

A quick look at the control variables shows results similar to prior papers in cash holdings. *Market-to-book* is positively and significantly related to *cash holdings* implying that firms with more growth opportunities hold more cash. *Cash flow* is also positively related to *cash holdings* suggesting that firms with more cash flow hold more cash in general. *Capital expenditures-to-assets* and *acquisitions-to-assets* are both negatively related to *cash holdings* at a 1 % level implying that firms with these expenditures hold less cash. *Leverage* is significantly negatively related to cash holdings suggesting that firms with larger amounts of debt hold less cash. Firms that are larger (*size*) hold relatively less cash, a finding that is significant at a 1 % level. Firms that have an investment grade bond rating (*investment grade dummy*) hold more cash, a finding that is significant at a 1 % level. The main difference in our results among control variables is that no relationship is found between firms that pay dividends (*dividend dummy*) and *cash holdings*. Prior papers have found that firms that paid more in dividends held less cash. Finally, *lagged cash holdings* has a positive relationship that is significant at a 1 % level with cash holdings.

In summary, when testing for the relationship between corporate cash holdings and interest rates a negative relationship is expected. While the negative relationship is found when examining the entire time period from 1970 to 2014, when testing the relationship using a threshold model numerous positive and insignificant relationships are found. The positive relationship is primarily concentrated in low and middle interest

rate ranges. Observations in these ranges include the 1990's and 2000's. In an attempt to explain why this relationship exists, additional controls are included in Section 6.

6 Tests for the non-negative relationship

Given the positive relationship was not driven by the marketable securities included in cash holdings, we attempt to explain why the positive relationship exists by controlling for other factors that might be driving the relationship during this time. Several additional explanations for the positive relationship are tested and discussed below. These explanations include the tax-based explanation, pension fund contributions, zero-leverage firms, financially constrained and unconstrained firms, firm governance, and high-tech firms.¹¹

6.1 Tax-based explanation

Originally introduced by Foley et al. (2007), the tax-based explanation suggests that firms facing higher repatriation taxes hold larger levels of cash, hold the cash abroad, and hold the cash in places that trigger high tax costs when repatriating earnings. The Association for Financial Professionals reports that due to high tax rates, United States multinational corporations have \$1 trillion in cash and cash equivalent investments outside of the United States.^{12 13} In 2004, Congress enacted the Homeland Investment Act (HIA) which temporarily reduced the tax to 5.25 % and repatriation surged. Pinkowitz et al. (2012) find that the HIA did not reduce cash holdings of multinational firms and put forth two possible explanations: either the incentives in the HIA were insufficient to affect corporate cash holdings or the HIA changed where firms store their cash and not the amount held. Companies holding cash abroad are forgoing the interest that could be earned in the US markets. Thus, we may be picking up on the relationship between the foreign cash holdings and the interest rate, which would be a spurious relationship.

In the analysis, a multinational firm is defined as a firm that reports pretax foreign income in Compustat.¹⁴ The data set is divided into domestic and multinational companies based on this criterion. For the tax-based explanation to be valid, it is expected that when dividing the data sets into domestic and multinational firms, the positive relationship should exist only in the multinational sample. Over this time, the relationship between *cash holdings* and the interest rates should be negative for the domestic firms.

Results can be found in Table 3. For brevity, only the coefficients for the marginal effects of the interest rates are reported. Columns 1 and 2 present results for the one threshold model. Columns 3 and 4 are for the two threshold model and Columns 5 and

¹¹ In addition to controlling for each of the following alternative explanations individually, we also controlled for them collectively, with the exception of the governance variable and constraint variables. The positive and statistically significant relationships remain. These results are available upon request.

¹² Available at <http://www.afponline.org/search.aspx?searchtext=repatriation> in the "AFP Policy Position on Repatriation."

¹³ A multinational firm is a firm that reports operations in a foreign country but is incorporated in the United States.

¹⁴ If Compustat reports that pretax foreign income is missing the value is coded as zero. In unreported results, the Compustat variable IDBFLAG (international, domestic, and both indicator) is used. The results are similar to those reported here and are available upon request.

Table 3 Tax-based explanation

	(1) One Threshold		(2)		(3) Two Thresholds		(4)		(5) Three Thresholds		(6)	
	Domestic	Multinational	Domestic	Multinational	Domestic	Multinational	Domestic	Multinational	Domestic	Multinational	Domestic	Multinational
Federal Funds Rate in Low Region	-0.0026263 (-1.59)	0.0032185 (0.88)	0.0113779*** (4.26)	0.0032185 (0.88)	0.0113779*** (4.26)	-0.1024021** (-2.32)	0.0067959*** (2.81)	-0.1024021** (-2.32)	0.0067959*** (2.81)	-0.0194097* (-1.71)	-0.0194097* (-1.71)	
Federal Funds Rate in Middle Region			0.0130538*** (4.29)		0.0130538*** (4.29)	-0.1152966*** (-2.60)		-0.1152966*** (-2.60)				
Federal Funds Rate in Lower Middle Region							0.001344 (0.23)		0.001344 (0.23)			-0.0243829* (-1.94)
Federal Funds Rate in Upper Middle Region							0.0034106 (0.97)		0.0034106 (0.97)			-0.0314403** (-2.53)
Federal Funds Rate in High Region	-0.00125*** (-12.17)	-0.000658 (-1.44)	-0.000283 (-1.64)	-0.000658 (-1.44)	-0.000283 (-1.64)	-0.01110*** (-2.80)	-0.000817*** (-6.22)	-0.01110*** (-2.80)	-0.000817*** (-6.22)			-0.00309*** (-2.65)
<i>N</i>	135993	35153	135993	35153	135993	35153	135993	35153	135993	35153	35153	35153
<i>Year Dummies</i>	No	No	No	No	No	No	No	No	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> ²	0.531	0.648	0.531	0.648	0.531	0.648	0.531	0.648	0.531	0.648	0.648	0.648

This table presents the empirical results when controlling for the tax based explanation. Multinational firms are defined as firms that report pretax foreign income in Computat. *Cash Holdings* is the dependent variable in all regressions. This table presents only the marginal effects for the interest rate thresholds. All other variables are defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is $p < .01$

6 present results for the three threshold model. The positive relationship is still prevalent amongst the domestic firms primarily with the interest rates in lower and middle regions. An interesting result is found when looking at the multinational companies; the relationship between *cash holdings* and interest rates are negative and statistically significant across all thresholds in the two and three thresholds models. Thus, it seems that the reason for the positive relationship cannot be explained by firms holding cash overseas.

6.2 Pension fund contributions

An additional test for an explanation for the positive relationship is that cash contributions made to pension funds during the 1980's and the 1990's were greater and thus larger amounts of cash were held to meet these obligations. According to the Employee Retirement Income Security Act of 1974, the contributions made to defined benefit (DB) pension funds are annually reviewed to ensure that the plans are funded accordingly. DB plans were the most popular form of pension plan in the 1980's and the 1990's. During times of economic turmoil, there is a chance that investments might fall below the well-funded level. In these cases, a company will have to make larger contributions and these contributions are often made with liquid corporate assets (Rauh 2009). Rauh (2006) showed that cash for required contributions leads to lower capital investment. Thus, the companies in the 1980's and the 1990's might have been holding more cash due to the larger cash contributions that were required.

The pension fund contribution hypothesis is tested using two unique variables. The first variable is pension expense, reported in Compustat Annual files, to total assets. The second variable is the mandatory pension expense variable used in Campbell et al. (2012). It measures the mandatory pension expense required to maintain well-funded status. It is calculated by the service costs plus the accumulated benefit obligation minus the fair value of pension plan assets divided by 30. This is all divided by total firm assets as of the previous year. The value is reported if the pension benefit obligation is greater than the fair value of pension plan assets, otherwise it is zero. Data to create the mandatory pension expense variable was obtained from Compustat Annual Pension database. If a variable is missing in the data base, then it is recorded as zero. The predicted relationship between *cash holdings* and the pension expense variables can vary depending on when the fiscal year data falls in accordance to the pension funding requirement. As a larger contribution to an underfunded pension is needed, the company might increase cash balances thus increasing the amount of cash and cash equivalents they report. However, once the company has made those contributions it could be that the firm holds less cash.

The results can be found in Table 4. For brevity, only the pension expense variables and marginal effect in the interest rate regions are reported. The pension expense to total assets variable is included in columns 1 through 3 and the mandatory pension expense variable is included in columns 4 through 6. The results from the one threshold model can be found in columns 1 and 4, the two threshold model results are in columns 2 and 5, and the three threshold model results are in columns 3 and 6.

Pension expense is negative and significantly related to *cash holding* at a 1 % level across all three models. When looking at the marginal effect, little to no change in the relationships between the interest rate regions and *cash holdings* are seen across all

Table 4 Pension fund contributions

	(1)	(2)	(3)	(4)	(5)	(6)
	Pension Expense			Mandatory Pension Expense		
	One Threshold	Two Thresholds	Three Thresholds	One Threshold	Two Thresholds	Three Thresholds
Pension Expense Variable	-0.162*** (-3.11)	-0.161*** (-3.09)	-0.174*** (-3.32)	0.520*** (3.43)	0.514*** (3.38)	0.552*** (3.63)
Federal Funds Rate in Low Region	0.0009117 (0.69)	0.0167264*** (6.79)	0.0095833*** (4.95)	0.0002455 (0.19)	0.0158205*** (6.40)	0.0083596*** (4.29)
Federal Funds Rate in Middle Region		0.0139032*** (4.84)			0.0130827*** (4.55)	
Federal Funds Rate in Lower Middle Region			0.003323 (0.70)			0.0019987 (0.42)
Federal Funds Rate in Upper Middle Region			0.0032167 (1.01)			0.0016259 (0.51)
Federal Funds Rate in High Region	-0.00132*** (-13.46)	-0.000228 (-1.34)	-0.000881*** (-6.92)	-0.00132*** (-13.55)	-0.000253 (-1.49)	-0.000921*** (-7.27)
<i>N</i>	171146	171146	171146	171100	171100	171100
<i>Corporate Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year Dummies</i>	No	No	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes	Yes	Yes
R ²	0.55	0.55	0.55	0.55	0.55	0.55

This table presents the empirical results for the random effects threshold regressions. *Cash Holdings* is the dependent variable in all regressions. *Pension Expense* is defined as the reported pension expense in Compustat divided by total assets. If pension expense is missing then it is set to zero. *Mandatory Pension Expense* is defined as the service costs plus the accumulated benefit obligation minus the fair value of pension plan assets divided by 30. This is all divided by total firm assets as of the previous year. This is calculated if the pension benefit obligation is greater than the fair value of pension plan assets. This table presents only the marginal effects for the interest rate thresholds and the pension expense variables. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is <.01

three models. *Mandatory pension expense* is positive and significantly related to *cash holdings* at a 1 % level across all thresholds. The differing relationships between the two pension variables signify that they are capturing two different relationships with cash holdings. Pension expense is an expense that the firm has already taken so a larger expense implies that the company holds less cash. However, the mandatory pension expense is an expense that firms will need to make to ensure funds are not underfunded. This is a forward looking variable that anticipates how much the firms will need to expense and thus has a positive relationship as firms built up cash for larger anticipated need. Again, the relationships between the interest rate regions and cash holdings change very little when including the pension variables. In conclusion, while *pension expense* and *mandatory pension expense* capture two different relationships with cash holdings, pension contributions do not explain the positive relationship between *cash holdings* and interest rates.

6.3 Zero-leverage firms

The mystery of why firms choose not to have any debt has led researchers to look into the characteristics of these companies. As reported in Strebulaev and Yang (2013), 14 % of large public non-financial US firms had zero outstanding debt in 2000. In addition, they find that zero-leverage firms and particularly dividend-paying, zero-leverage firms have higher cash balances than matched firms. In fact, they find that 75 % of the time zero-leverage firms hold higher levels of cash than the matched firms. We test for whether the results are being driven by the zero-leverage firms who have to maintain higher cash balances.

In our data set, zero-leverage firms are holdings substantial amounts of *cash holdings including marketable securities* and *cash holdings*. The mean values of the two cash holdings variables for firms with zero leverage and positive values of leverage are presented in appendix Table 10. The mean measure of *cash holdings including marketable securities* for zero-leverage firms ranges from 0.2212 in 1970 to 0.4309 in 2014. The variation in *cash holdings* is just as drastic ranging from 0.0471 in 1970 to 0.3145 in 2014. The mean of both measures is substantially above the mean of the corresponding measure for firms with leverage. Thus, it is of interest to control for the relationship excluding the zero-leverage firms. It is also interesting to divide them out because a substantial increase in the mean of *cash holdings* for zero-leverage firms takes place in 1988, which is when the large increase shown in Panel A of Fig. 2 takes place. Thus, the baseline regressions are repeated separating out zero-leverage firms from firms with positive amounts of leverage.

The results are presented in Table 5.¹⁵ The results for firms with positive amounts of leverage are found in the odd columns and the results for firms with zero leverage can be found in the even columns. Focusing on the marginal results for the interest rate thresholds, the results remain very similar to those seen in previous tables. Particularly when looking at the two threshold model in column 3, the relationship between *cash holdings* and the federal funds rate is positive and statistically significant at a 1 % level

¹⁵ In unreported results, almost zero-leverage firms are also excluded. Strebulaev and Yang (2013) classify almost zero-leverage firms as firms whose leverage ratio is less than 5 %. Similar results are found as when excluding zero-leverage firms and in the baseline regression. These results are available upon request.

Table 5 Excluding zero-leverage firms

	(1) One Threshold		(2)		(3) Two Thresholds		(4)		(5) Three Thresholds		(6)	
	Leverage >0		Leverage = 0		Leverage >0		Leverage = 0		Leverage >0		Leverage = 0	
Federal Funds Rate in Low Region	0.0018096 (1.44)		-0.0229743 (-3.55)		0.0133195*** (5.93)		0.0480842*** (2.70)		0.007809*** (4.30)		0.0063116 (0.54)	
Federal Funds Rate in Middle Region					0.0079203*** (2.96)		0.0731378*** (3.74)					
Federal Funds Rate in Lower Middle Region									0.0046642 (1.04)		-0.0000347 (-0.00)	
Federal Funds Rate in Upper Middle Region									-0.0008811 (-0.30)		0.026318 (1.37)	
Federal Funds Rate in High Region	-0.00119*** (-13.27)		-0.00351*** (-5.15)		-0.000410*** (-2.71)		0.00152 (1.12)		-0.000961*** (-8.28)		-0.00133 (-1.36)	
<i>N</i>	152461		18685		152461		18685		152461		18685	
<i>Corporate Controls</i>	Yes		Yes		Yes		Yes		Yes		Yes	
<i>Year Dummies</i>	No		No		No		No		No		No	
<i>Industry Dummies</i>	Yes		Yes		Yes		Yes		Yes		Yes	
<i>Mundlak-Chamberlain Devices</i>	Yes		Yes		Yes		Yes		Yes		Yes	
<i>R</i> ²	0.494		0.522		0.494		0.522		0.494		0.522	

This table presents the empirical results for the random effects threshold regressions. *Cash Holdings* is the dependent variable in all regressions. Firms with zero-leverage are separated from the sample and independently reported. This table presents only the marginal effects for the interest rate thresholds. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is <.01

for interest rates in the low and middle region. For firms with zero leverage, the relationship remains positive and statistically significant, but does have a larger coefficient in both the lower and middle interest rate regions. The results are similar for the three threshold model, with the exception that the relationship between cash holdings and the federal funds rate for zero-leverage firms is not statistically significant in all threshold regions. Thus, zero-leverage firms are not driving the results.

6.4 Constrained and unconstrained firms

In an additional test, the relationship is examined across financially constrained and unconstrained firms. Almeida et al. (2004) show that constrained manufacturing firms, when measured by firm size, bond rating, and commercial paper, hold more cash than unconstrained manufacturing firms. Thus, it could be that the constrained firms are holding more cash for financial reasons and are not taking into account interest rates when holding cash.

We follow Almeida et al. (2004) and define financially constrained firms three different ways.¹⁶ The first is based on firm size. Firms are sorted into deciles each year based on total assets and the top (bottom) three deciles are defined as unconstrained (constrained) firms. The argument is that smaller firms are typically younger and less well known. The second and third measures are bond and commercial paper ratings. These are measured similarly, with the exception that the bond rating data is the S&P long-term rating and the commercial rating data is the S&P short-term rating. If a firm has never had a rating and holds a positive value of debt then the firm is classified as constrained. Unconstrained firms are classified as firms that have been rated during the sample.¹⁷ The argument here is that firms without ratings do not have the ease of access to external financing.

Table 6 displays the mean of *cash holdings including marketable securities* and *cash holdings* for constrained and unconstrained firms. All three measures of financial constraint provide similar results. On average, constrained firms hold larger amounts of cash and marketable securities relative to assets than unconstrained firms. In addition, constrained firms, on average, hold larger amounts of cash and cash equivalents relative to assets than unconstrained firms. Thus, it could be that the constrained firms are driving the results.

The regression results based on size are presented in Table 7.¹⁸ Results are presented based on the one threshold model in Columns 1 and 2, two threshold model in Columns 3 and 4, and three threshold model in Columns 5 and 6. Even columns present results for constrained firms and odd columns present results for unconstrained firms. As in prior tables only the variables of interest are reported. Both constrained and unconstrained firms, regardless of how they are measured, have numerous positive and statistically

¹⁶ Almeida et al. (2009) also use the KZ Index to classify constrained and unconstrained firms, however they find that this measure is negatively correlated with the other measures so it is excluded from our analysis.

¹⁷ In addition, Almeida et al. (2004) classify firms with no rating and no debt as unconstrained. In unreported regressions, when classifying these firms as unconstrained we find that unconstrained firms have larger *cash holdings*, which is contrary to the finding of Almeida et al. (2004). Upon further inspection, firms with no leverage appear to be driving this result. Thus, firms with no leverage and no bond rating are excluded from the analysis. However, including them does not affect the regression results.

¹⁸ The results based on the bond and commercial paper ratings can be found in appendix Table 11.

Table 6 Constrained and unconstrained firm summary statistics

		Mean		Number of Observations
		Cash Holdings Including Marketable Securities	Cash Holdings	
1	Firm Size			
	Constrained	0.2019	0.1495	57793
	Unconstrained	0.0916	0.0562	58447
2	Bond Rating			
	Constrained	0.1382	0.0958	120895
	Unconstrained	0.0962	0.0631	53525
3	Comm. Paper Rating			
	Constrained	0.1287	0.0891	156346
	Unconstrained	0.0759	0.0464	16472

This table presents summary statistics on the mean of *cash holdings including marketable securities* and *cash holding* for the three constrained and unconstrained classifications. Firms classified by firm size are sorted into deciles each year based on total assets then the top (bottom) three deciles are defined as unconstrained (constrained) firms. The second and third measures are bond and commercial paper ratings. These are measured similarly, with the exception that the bond rating data is the S&P long-term rating and the commercial rating data is the S&P short-term rating. If a firm has never had a rating and holds a positive value for debt then the firm is classified as constrained. Unconstrained firms are classified as firms that have been rated during the sample. Firms with no leverage and no bond rating are excluded from the sample

significant relationships across all threshold models. However, the unconstrained firms do not show the expected negative relationship especially during the lower interest rate regions. Thus, when separating firms by financial constraints some of the coefficients are reduced, however it does not explain all the positive relationships found.

6.5 Alternative explanations

In addition to the above explanations, additional explanations are tested which we do not report but do discuss.¹⁹ The first is that the positive relationship could be driven by firms that are poorly governed. Dittmar and Mahrt-Smith (2007) find that poorly governed firms do not efficiently manage cash balances and have a lower value of cash. Thus, these poorly governed firms may not consider interest rates when deciding whether to hold cash. It could be that these inefficient firms are driving the positive relationship between cash holdings and interest rates.

The commonly used measures of corporate governance are the Gompers et al. (2003) (GIM) index and the Bebchuk et al. (2009) (E) index. The GIM index is available from Risk Metrics and measures the number of antitakeover provisions a firm has. The E index is available on Lucian Bebchuk's website and uses six antitakeover provisions that Bebchuk et al. (2009) have shown have the greatest impact on firm value.²⁰ The variables are reported approximately every 2 to 3 years (1990, 1993, 1995, 1998, etc.). Similar to prior literature, we assume that the index remains

¹⁹ All results are available upon request.

²⁰ Data can be found at www.law.harvard.edu/faculty/bebchuk/data.shtml.

Table 7 Constrained and unconstrained firms

	(1) One Threshold		(2)		(3) Two Thresholds		(4)		(5) Three Thresholds		(6)	
	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained	Unconstrained	Constrained
Federal Funds Rate in Low Region	0.0099497*** (8.15)	0.0014547 (0.42)	0.0173657*** (7.58)	0.0260565*** (3.55)	0.0173657*** (7.58)	0.0260565*** (3.55)	0.0173657*** (7.58)	0.0260565*** (3.55)	0.0127056*** (7.46)	0.0198313*** (3.60)	0.0127056*** (7.46)	0.0198313*** (3.60)
Federal Funds Rate in Middle Region			0.003862 (1.43)	0.0276739*** (3.30)	0.003862 (1.43)	0.0276739*** (3.30)						
Federal Funds Rate in Lower Middle Region									0.0133152*** (3.01)	0.0166436 (1.27)	0.0133152*** (3.01)	0.0166436 (1.27)
Federal Funds Rate in Upper Middle Region									-0.0041761 (-1.44)	0.0163623* (1.92)	-0.0041761 (-1.44)	0.0163623* (1.92)
Federal Funds Rate in High Region	-0.000738*** (-8.82)	-0.00153*** (-5.52)	-0.000247* (-1.71)	0.0002 (0.39)	-0.000247* (-1.71)	0.0002 (0.39)	-0.000247* (-1.71)	0.0002 (0.39)	-0.000655*** (-6.73)	-0.000569 (-1.50)	-0.000655*** (-6.73)	-0.000569 (-1.50)
<i>N</i>	54356	46840	54356	46840	54356	46840	54356	46840	54356	46840	54356	46840
<i>Corporate Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year Dummies</i>	No	No	No	No	No	No	No	No	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> ²	0.594	0.484	0.594	0.484	0.594	0.484	0.594	0.484	0.594	0.484	0.594	0.484

This table presents the empirical results for the random effects threshold regressions of constrained and unconstrained firms. *Cash Holdings* is the dependent variable in all regressions. Firms classified by firm size are sorted into deciles each year based on total assets then the top (bottom) three deciles are defined as unconstrained (constrained) firms. This table presents only the marginal effects for the interest rate thresholds. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is <.01

unchanged during the unreported years. There are two restrictions when using the above indexes. The first is that they are only available from 1990 to 2006. Thus, we are restricted to only testing for the relationship between cash holdings and interest rates during this time. Second, the data only cover S&P 1500 firms. Thus, the data set is substantially reduced.²¹

To test whether poorly governed firms are driving the positive relationship, the data is split into poorly governed firms and well governed firms. Firms are sorted into terciles each year. Poorly governed firms are defined as the highest tercile of firms and well governed firms are defined as the lowest tercile of firms. Very few of the relationships are statistically significant. Furthermore, those relationships that are significant are positive and exist among well governed firms, which was not as predicted.

The final explanation is that high-tech firms are driving the results. Zhou (2009) found that the documented increase in cash holdings is among high-tech firms and that non-high tech firms' cash holdings remain relatively stable over 1980–2007. Zhou follows Brown et al. (2009) and defines a high-tech industry by the following 3-digit SIC codes: drugs (SIC 283), office and computing equipment (SIC 357), communications equipment (SIC 366), electronic components (SIC 367), scientific instruments (SIC 382), medical instrument (SIC 384), and software (SIC 737).²² The baseline regressions are repeated excluding these high tech industries. Results remain similar as in previous regressions.

7 Quantile regression

In further tests, results are presented based on quantile regressions. Whereas most regression estimates are based on the conditional mean of the response variables, the quantile regressions allow one to estimate the data at either the median or other quantiles of the response variable. The advantage to using the quantile regression is that it is robust against outliers in the data. It is also useful in estimating a relationship between variables in cases where no or a weak relationship exists to see if differing relationships exist among different ranges of the dependent variable.

The final results presented are based on the quantile regressions for the threshold models.²³ It is of interest to see if firms holding cash in a particular range are driving the results. The quantile regression is also useful because cash holdings is highly skewed to the right. We estimate the three threshold model at nine quantiles, namely the 10th, 20th, 30th, 40th, 50th, 60th, 70th, 80th, and 90th. All control variables are included from the threshold regressions including the industry dummies. However, the Mundlak (1978) and Chamberlain (1980) devices are not included.

²¹ Prior to splitting the sample into well and poorly-governed firms, the regressions are repeated with the smaller set of firms. Results similar to the ones presented in the paper are not found. There are numerous insignificant relationships across all threshold variables.

²² Brown et al. (2009) use the definition provided by the United States Department of Commerce for high-tech firms. This definition can be found at: "An Assessment of United States Competitiveness in High-Technology Industries," United States Department of Commerce, February 1983.

²³ In unreported regressions, the quantile regressions are run with just *interest rate_t*. It is found that across all three models *interest rate_t* is negatively and significantly related to cash holdings excluding cash equivalents at a 1 % level.

Results based on the three threshold model are presented in Table 8.²⁴ For brevity, only the marginal effects for each data set are presented. Columns 1–9 detail the relationship based on the nine quantiles. Results in the first column referred to firms with lower amounts of *cash holdings* and rises until quantile 90, which represents the highest amounts.

When looking at the lower middle region, firms with higher levels of *cash holdings* (quantiles 40–90) have a positive relationship between cash holdings and interest rates. The coefficient declines in value as we move to lower quantiles, however, it never becomes negative and statistically significant. When looking at the upper middle region, firms with lower levels of *cash holdings* (quantiles 10–50) have a positive relationship between cash holdings and interest rates. The coefficient declines in value as we move to the right, becoming negative and statistically significant for firms with the highest level of cash holdings (quantile 90). In conclusion, it is found that not one particular group of firms is driving the results. Firms with lower amounts of *cash holdings* are driving some of the relationships and firms with larger amounts are driving other relationships. Thus, it appears that firms hold cash in response to firm-specific needs and not necessarily in response to interest rates.

8 Conclusion

This paper examines the relationship between cash holdings and interest rates as measured by the federal funds rate. To test the relationship, a random effects threshold model is used and tested over multiple thresholds. To exclude capturing the positive relationship between marketable securities and interest rates, a new cash holdings variable is used that includes cash and cash equivalents, but not marketable securities. Even with the new cash holdings variable, several positive relationships still exist between cash holdings and interest rates, particularly with interest rates from the 1990's forward.

To further examine what is driving the positive relationship, several alternative explanations are tested: the tax-based explanation, pension fund contributions, zero-leverage firms, financially constrained and unconstrained firms, firm governance, and high-tech firms. After dividing the data sets into domestic and multinational companies, the positive relationship is found for domestic firms. Thus, the tax-based explanation does not explain the relationship. After including two measures of pension contributions as an explanatory variable, the positive relationship is still unaffected. It is found that zero-leverage firms and high-tech firms hold large amounts of cash; after omitting these firms separately from the data sets the positive relationship continues to hold. After dividing the data up into financially constrained and unconstrained firms based on three separate measures, the positive relationship still exists for both financially constrained and unconstrained firms. Lastly, the positive relationship is still found when controlling for firm governance. Thus, none of the explanations provided are able to explain why a negative relationship does not exist. Finally, quantile regressions find that there is not one group of firms that are driving the positive relationship as firms with low cash holdings are driving some of the results and firms with high cash holding are driving the remainder of the results.

²⁴ Results based on the one and two threshold model are provided in appendix Table 12.

Table 8 Quantile regression

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	10	20	30	40	50	60	70	80	90
Interest Rates in Low Region	0.0032202*** (7.53)	0.0055545*** (10.19)	0.0072979*** (12.77)	0.0081728*** (13.57)	0.0087354*** (13.53)	0.0093571*** (12.01)	0.0104438*** (11.55)	0.0121249*** (9.42)	0.0109909*** (5.34)
Interest Rates in Lower Middle Region	0.0005703 (0.60)	0.0018569* (1.78)	0.0015367 (1.26)	0.0030297** (2.29)	0.0027956* (1.90)	0.0044466** (2.26)	0.0114939*** (4.15)	0.0178619*** (4.44)	0.0158664* (1.92)
Interest Rates in Upper Middle Region	0.0046338*** (7.32)	0.0047392*** (6.94)	0.004056*** (5.80)	0.0037971*** (5.06)	0.0027586*** (3.29)	0.000864 (0.78)	-0.0009636 (-0.67)	-0.0036295 (-1.60)	-0.0205746*** (4.29)
Interest Rates in High Region	-0.0000445* (-1.77)	-0.0000718*** (-2.64)	-0.000117*** (-4.29)	-0.000148*** (-5.07)	-0.000191*** (-6.03)	-0.000288*** (-7.57)	-0.000439*** (-8.85)	-0.000680*** (-9.43)	-0.00134*** (-10.52)
N	171146	171146	171146	171146	171146	171146	171146	171146	171146
Corporate Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	No	No	No	No	No	No	No	No	No
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak-Chamberlain Devices	No	No	No	No	No	No	No	No	No
R ²	0.514	0.522	0.527	0.529	0.532	0.536	0.54	0.541	0.52

This table presents the empirical results for the quantile regression of all firms. *Cash Holdings* is the dependent variable in all regressions. This table presents only the marginal effects for the interest rate thresholds. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is p <.01

In conclusion, we find a positive relationship between cash holdings and interest rates. Several explanations are examined, but none can explain the positive relationship between interest rates and cash holdings. We conclude that the relationship is driven by a multitude of firm characteristics and suggests that firms are not holding cash purely based on interest rates and a revised model might need to be presented that examines the cash holding practice of firms when looking at the interest rate environment.

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Appendix

Table 9 Variables

Variable	Definition
Cash Holdings Including Marketable Securities	Cash, Cash Equivalents, and Marketable Securities divided by Total Assets
Cash Holdings	Cash and Cash Equivalents Divided by Total Assets
Market-to-Book	Market Value per Share to the stated Book Value of Equity
Cash Flow	Earnings after Interest, Taxes, and Dividends, but before Depreciation, divided by Total Assets
Net Working Capital-to-Assets	Net Working Capital minus Cash, Cash Equivalents, and Marketable Securities divided by Total Assets
Capital Expenditure-to-Assets	Earnings after Interest, Taxes, and Dividends, but before Depreciation, divided by Total Assets
Leverage	Long Term Debt plus Current Debt divided by Total Assets
R&D-to-Sales	Research and Development divided by Sales. If R&D is missing in Compustat then it is set to zero.
Acquisitions-to-Assets	Acquisitions divided by Total Assets. If Acquisitions is missing in Compustat then it is set to zero.
Dividend Dummy	Indicator variable equal to one if the company pays a common dividend and zero otherwise
Investment Grade Dummy	Indicator variable equal to one if a company has a long-term bond rating of BBB- and above or a short-term commercial paper rating of A-3 and above, otherwise the dummy equals zero
Size	Natural log of a firm's Total Assets in 2009 dollars, using the consumer price index to account for inflation
Cash Flow Riskiness	The standard deviation of industry cash flows calculated as suggested by Opler et al. (1999). It requires the standard deviation of cash flows for the previous 20 years, if available. We do require that firms have at least 5 years of data to calculate cash flow riskiness. Observations are then averaged across the two-digit SIC code.

This table provides the corporate variable names and definitions used in the paper

Table 10 Cash holdings of zero-leverage firms

Year	No Leverage			Leverage > 0		
	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings
1970	56	0.2212	0.0471	1020	0.0665	0.0410
1971	152	0.2481	0.0729	2302	0.0793	0.0464
1972	184	0.2391	0.0764	2483	0.0796	0.0451
1973	175	0.2244	0.0646	2664	0.0727	0.0407
1974	247	0.2417	0.0987	4117	0.0700	0.0433
1975	298	0.2670	0.1025	4232	0.0781	0.0478
1976	313	0.2617	0.1008	4250	0.0840	0.0480
1977	293	0.2576	0.1059	4219	0.0815	0.0471
1978	282	0.2562	0.0920	4134	0.0794	0.0430
1979	256	0.2769	0.1051	3950	0.0790	0.0402
1980	260	0.3080	0.1041	3802	0.0843	0.0397
1981	266	0.3408	0.0864	3580	0.0974	0.0402
1982	261	0.3393	0.0931	3430	0.0969	0.0388
1983	280	0.3566	0.0923	3269	0.1165	0.0435
1984	250	0.3810	0.0954	3133	0.1115	0.0420
1985	229	0.3530	0.1034	3094	0.1085	0.0422
1986	257	0.3739	0.1222	3081	0.1148	0.0445
1987	276	0.3727	0.1379	3108	0.1146	0.0521
1988	351	0.3556	0.2126	3949	0.1096	0.0753
1989	387	0.3597	0.2351	4252	0.1064	0.0828
1990	414	0.3589	0.2301	4378	0.1039	0.0825

Table 10 (continued)

Year	No Leverage			Leverage > 0		
	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings
1991	465	0.3847	0.2596	4528	0.1167	0.0899
1992	544	0.3798	0.2464	4707	0.1211	0.0902
1993	636	0.3742	0.2287	4883	0.1248	0.0903
1994	656	0.3536	0.2117	5063	0.1188	0.0848
1995	727	0.3592	0.2338	5528	0.1246	0.0910
1996	788	0.3889	0.2594	5614	0.1408	0.1038
1997	779	0.3968	0.2618	5416	0.1396	0.1015
1998	773	0.3896	0.2570	5408	0.1416	0.1064
1999	738	0.4129	0.2806	5346	0.1461	0.1075
2000	714	0.4261	0.2873	5072	0.1432	0.1046
2001	660	0.4124	0.2844	4670	0.1404	0.1037
2002	660	0.4064	0.2698	4372	0.1432	0.1078
2003	722	0.4221	0.2985	4117	0.1566	0.1212
2004	730	0.4384	0.2829	3935	0.1691	0.1239
2005	746	0.4316	0.2682	3730	0.1696	0.1251
2006	728	0.4344	0.2751	3562	0.1690	0.1256
2007	686	0.4403	0.2967	3392	0.1627	0.1225
2008	626	0.3986	0.2996	3289	0.1481	0.1204
2009	651	0.3896	0.2923	3172	0.1645	0.1327
2010	652	0.3937	0.2861	3030	0.1683	0.1362
2011	623	0.4114	0.3033	2946	0.1627	0.1333

Table 10 (continued)

Year	No Leverage			Leverage > 0		
	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings	Number of Observations	Cash Holdings Including Marketable Securities	Cash Holdings
2012	615	0.4105	0.3061	2979	0.1599	0.1313
2013	608	0.4067	0.3117	2894	0.1704	0.1395
2014	526	0.4309	0.3145	2568	0.1691	0.1363

This table presents the mean of *Cash Holdings Including Marketable Securities* and *Cash Holdings* for the entire sample of zero-leverage firms by year

Table 11 Additional constrained and unconstrained firms

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Bond Rating						
One Threshold	Unconstrained	Constrained	Two Threshold	Constrained	Three Threshold	Constrained
Federal Funds Rate in Low Region	0.0025075* (1.73)	-0.00014 (-0.08)	0.0137487*** (3.89)	0.0092245*** (3.28)	0.0058689*** (2.70)	0.006068*** (2.43)
Federal Funds Rate in Middle Region			0.0071083* (1.71)	0.0079336** (2.39)		
Federal Funds Rate in Lower Middle Region				0.0106854** (1.98)		0.0004658 (0.08)
Federal Funds Rate in Upper Middle Region				-0.0130259*** (-3.32)		0.0029716 (0.78)
Federal Funds Rate in High Region	-0.000831*** (-6.57)	-0.00112*** (-10.05)	-0.0000849 (-0.35)	-0.000402** (-2.20)	-0.000650*** (-4.09)	-0.000857*** (-5.94)
<i>N</i>	49173	104812	49173	104812	49173	104812
<i>Corporate Controls</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Year Dummies</i>	No	No	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> ²	0.564	0.482	0.564	0.482	0.564	0.482
Panel B: Commercial Paper Rating						
One Threshold	Unconstrained	Constrained	Two Threshold	Constrained	Three Threshold	Constrained
Federal Funds Rate in Low Region	0.0087646*** (5.50)	-0.0009335 (0.67)	0.0116436*** (4.27)	0.0108586*** (4.41)	0.0101402*** (4.24)	0.005346*** (2.64)

Table 11 (continued)

Federal Funds Rate in Middle Region	-0.0007191 (-0.21)	0.0084386*** (2.87)		
Federal Funds Rate in Lower Middle Region		0.001909 (0.33)	0.0037458 (0.76)	
Federal Funds Rate in Upper Middle Region		-0.173162*** (-3.89)	-0.0000124 (-0.00)	
Federal Funds Rate in High Region	-0.000261 (-1.52)	-0.000407** (-2.45)	-0.000373*** (-2.40)	-0.000959*** (-7.49)
<i>N</i>	15502	137086	15502	137086
<i>Corporate Controls</i>	Yes	Yes	Yes	Yes
<i>Year Dummies</i>	No	No	No	No
<i>Industry Dummies</i>	Yes	Yes	Yes	Yes
<i>Mundlak-Chamberlain Devices</i>	Yes	Yes	Yes	Yes
<i>R</i> ²	0.657	0.488	0.657	0.488

This table presents the empirical results for the random effects threshold regressions of constrained and unconstrained firms. *Cash Holdings* is the dependent variable in all regressions. The measures are bond and commercial paper ratings. These are measured similarly, with the exception that the bond rating data is the S&P long-term rating and the commercial rating data is the S&P short-term rating. If a firm has never had a rating and holds a positive value for debt then the firm is classified as constrained. Unconstrained firms are classified as firms that have been rated during the sample. Firms with no leverage and no bond rating are excluded from the sample. This table presents only the marginal effects for the interest rate thresholds. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is $p < .01$

Table 12 Additional quantile regression

Panel A: One Threshold									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Interest Rates in Low Region	0.0020977*** (7.71)	0.0032991*** (9.82)	0.0044719*** (11.89)	0.0053532*** (13.36)	0.0060902*** (14.10)	0.0067706*** (12.26)	0.0078662*** (11.76)	0.0078227*** (7.58)	0.0013605 (0.84)
Interest Rates in High Region	-0.0000523*** (-2.70)	-0.000114*** (-5.62)	-0.000178*** (-8.80)	-0.000242*** (-11.27)	-0.000314*** (-13.28)	-0.000452*** (-15.79)	-0.000700*** (-18.18)	-0.00119*** (-19.62)	-0.00228*** (-21.04)
N	171146	171146	171146	171146	171146	171146	171146	171146	171146
Corporate Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	No	No	No	No	No	No	No	No	No
Industry Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mundlak-Chamberlain Devices	No	No	No	No	No	No	No	No	No
R ²	0.513	0.522	0.526	0.529	0.532	0.536	0.54	0.541	0.519
Panel B: Two Thresholds									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Interest Rates in Low Region	0.0009598* (1.77)	0.0031597*** (5.04)	0.0041165*** (6.29)	0.0060802*** (8.75)	0.0074688*** (10.05)	0.0095906*** (10.63)	0.121992*** (10.86)	0.0180356*** (11.44)	0.0255782*** (10.48)
Interest Rates in Middle Region	-0.0006888 (-1.12)	0.0004845 (0.72)	0.0004332 (0.63)	0.0017241** (2.34)	0.0024625*** (3.10)	0.0038826*** (3.98)	0.006109*** (4.71)	0.0132088*** (6.96)	0.0275336*** (7.65)
Interest Rates in High Region	-0.000127*** (-3.51)	-0.000121*** (-2.98)	-0.000197*** (-4.90)	-0.000184*** (-4.24)	-0.000210*** (-4.47)	-0.000250*** (-4.49)	-0.000391*** (-5.47)	-0.000464*** (-4.72)	-0.000610*** (-3.88)
N	171146	171146	171146	171146	171146	171146	171146	171146	171146
Corporate Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Dummies	No	No	No	No	No	No	No	No	No

Table 12 (continued)

<i>Industry Dummies</i>	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
<i>Mandlak-Chamberlain Devices</i>	No	No	No	No	No	No	No	No	No	No	No
R^2	0.513	0.522	0.526	0.529	0.532	0.536	0.54	0.541	0.54	0.541	0.52

This table presents the empirical results for the quantile regressions of all firms. *Cash Holdings* is the dependent variable in all regressions. This table presents only the marginal effects for the interest rate thresholds. All other variables are included and defined in Table 1. T-statistics are in parentheses and significance is denoted by * where the p-value is <.10, ** where the p-value is <.05, and *** where the p-value is $p < .01$

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