Interest Rates and Investment Redux

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Abstract

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1 Introduction

The apparent lack of sensitivity of business fixed investment to movements in interest rates has led Blanchard (1986) to remark famously that "it is well known that to get the user cost to appear at all in an investment equation, one has to display more than the usual amount of econometric ingenuity." More than a quip, this puzzling phenomenon is at odds with the conventional view of the monetary policy transmission mechanism, according to which the monetary authorities through open market operations move short-term interest rates to influence the cost of capital and, consequently, spending on durable goods, such as fixed investment, inventories, housing, and consumer durables; see, for example, Bernanke and Gertler (1995).

In this paper, we revisit this long-standing apparent empirical anomality. We do so by constructing a new data set that links income and balance sheet information for more than 1,100 large U.S. nonfinancial corporations to interest rates on their publicly-traded debt. Covering the last thirty years, this new data set enables us to evaluate and quantify empirically the relationship between firms' investment decisions and fluctuations in the *firm-specific* marginal financing costs as measured by the changes in secondary market prices of firms' outstanding bonds.

Our results indicate that business fixed investment is highly sensitive—both economically and statistically—to movements in firm-specific real interest rates. The interest-sensitivity of capital formation is robust to the inclusion of various measures of investment opportunities emphasized by frictionless neoclassical models as well as firm-level measures of expected default risk. Nevertheless, investment spending remains, *ceteris paribus*, significantly correlated with proxies for changes in firms' net worth or internal funds.

The remainder of the paper is organized as follows. In Section 2, we review the existing evidence—at both the macro and micro levels—on the link between financing costs and investment spending. Section 3 describes our new data set and highlights its key feature. Section 4 outlines our empirical methodology and presents our benchmark results. In Section 5, we focus on the 1990–2004 period, a part of our sample characterized by a fully developed market for both investment- and speculative-grade corporate debt. For this subsample period, we have also merged our firm-level monthly bond yields with market-based measures of expected default risk widely used by financial markets participants. In addition, we utilize our interest rate data to construct neoclassical user cost of capital at the firm level, taking into account depreciation, expected capital gains (or losses), movements in the relative price of capital, and tax treatment of investment and capital income.

2 Financing Costs and Investment Spending

In this section, we review both the macro and the micro evidence on the link between interest rates and capital spending.

3 Data Description

Our data set is an unbalanced panel of more than 1,100 publicly-traded firms in the U.S. nonfarm nonfinancial corporate sector covering the period 1973 to 2004. The distinguishing feature of the firms in our sample is that a part of their long-term debt—in many cases, a significant portion—is in form of bonds that are actively traded in the secondary market. For these firms, we have linked monthly market prices of their outstanding securities to annual income and balance sheet statements from Compustat. For the last decade and a half of the sample period, we have also linked this data to option-theoretic measures of default risks that are widely used by market participants. We now turn to the construction of our key variables: firm-specific interest rates and key income and balance sheet variables.

3.1 Sources and Methods

Bond yields: We obtained month-end market prices of outstanding long-term corporate bonds from the Lehman/Warga (LW) and Merrill Lynch (ML) databases. These two data sources include prices of nearly all dollar-denominated bonds publicly issued in the U.S. corporate cash market. The ML database is a proprietary data source of *daily* bond prices that starts in 1997. Focused on the most liquid securities, bonds in the ML database must have a remaining term-to-maturity of at least one year, a fixed coupon schedule, and a minimum amount outstanding of $100 million for below investment-grade and $150 million for investment-grade issuers. By contrast, the LW database of *month-end* bond prices has a somewhat broader coverage and is available from 1973 through mid-1998 (see Warga (1991) for details). For securities

Table 1: Summary Statistics of Bond Characteristics

Variable	Mean	Std. Dev.	Min	Median	Max
# of bonds per firm/month	3.28	4.01	1.00	2.00	57.00
Mkt. Value of Issue[a] ($mil.)	267.1	298.2	1.2	197.9	6,767.3
Maturity[b] (years)	13.8	9.4	2.0	10.0	50.0
Composite Rating (S&P)	-	-	D	A3	AAA
Coupon Rate (%)	7.83	2.19	0.00	7.58	17.50
Nominal Yield (%)	8.52	2.92	0.17	8.04	35.31
Real Yield[c] (%)	4.97	2.63	−4.07	4.74	29.96

Panel Dimensions

Obs. = 374,133 N = 6,290 bonds

Min. Tenure = 1   Median Tenure = 45   Max. Tenure = 301

NOTES: Sample period: Monthly data from January 1973 to December 2004 ($T = 382$).
[a]Market value of the outstanding issue deflated by the CPI.
[b]Maturity at issue date.
[c]Nominal yield less the percent change in the previous month's core CPI from twelve months prior.

with market prices in both the LW and LM databases, we spliced the option-adjusted yields at month-end—a component of the bond's yield that is not attributable to embedded options—across the two data sources.

To ensure that we are measuring financing costs of different firms at the same point in their capital structure, we limited our sample to only senior unsecured issues. To covert the monthly nominal bond yields into real terms, we employed a simplifying assumption that the expected inflation in period t is equal to the last period's realized annual core CPI inflation. Specifically, letting y_{it}^k denote the nominal yield (in percent per annum) on bond k of firm i at the end of month t, we computed the corresponding real yield r_{it}^k according to

$$r_{it}^k = y_{it}^k - 100 \times \ln\left(\frac{\text{CPI}_{t-1}}{\text{CPI}_{t-13}}\right),$$

where CPI denotes the level of the Consumer Price Index, excluding its food and energy components.

Table 1 contains summary statistics for the key characteristics of bonds in our sample.[1] Note that a typical firm has only a few bond issues outstanding—the median firm, for example, has two bond issues trading at any given month. Nevertheless, this distribution is highly positively skewed, and some firms can have more than fifty different bond issues trading in the market at a point in time. The distribution of the real market values of these issues is similarly skewed, with the range running from $1.2 million to more than $6.7 billion. Not surprisingly, the maturity of these debt instruments is fairly long, with the average maturity at issue of about 14 years. Although our sample spans the entire spectrum of credit quality—from "single D" to "triple A"—the median bond/month observation, at "A3," is solidly in the investment-grade category.

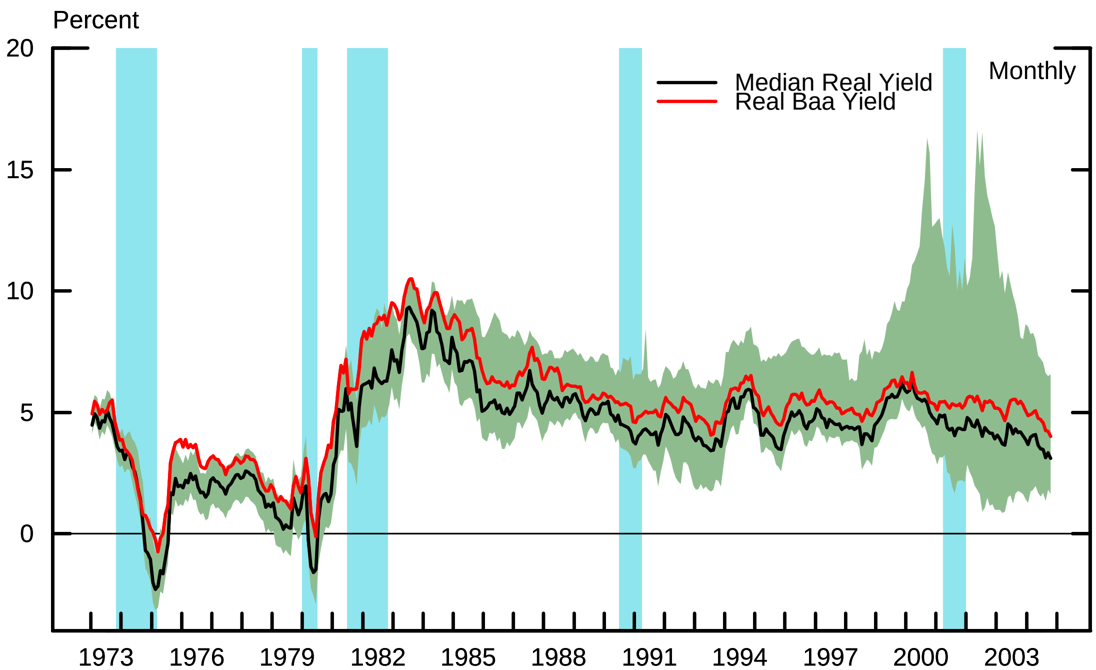
Turning to returns, the (nominal) coupon rate on these bonds averaged 7.83 percent during our sample period, while the average total nominal return, as measured by the nominal yield, was 8.52 percent per annum. Reflecting the wide range of credit quality, the distribution of nominal yields is fairly wide, with the minimum of 17 basis points and the maximum of more than 35 percent. In real terms, these bonds yielded about 5 percent per annum during our sample period, with the standard deviation of 2.6 percent.

Figure 1 depicts the time-series evolution of the cross-sectional distribution of real yields for the bonds in our sample (see Table 1). For comparison, we also plotted the real yield on all nonfinancial corporate bonds carrying the Moody's Baa credit rating, calculated using the same methodology as in the case of our bond-level data. Several features in Figure 1 are worth noting. First, as evidenced by the closeness of the 95th and 5th percentiles, there is surprisingly little cross-sectional dispersion in real yields until the second half of the 1980s. The narrowness of the distribution before the mid-1980s reflects in large part the fact that the secondary market for corporate debt during this time period was limited largely to investment-grade issues at the upper end of the credit-quality spectrum. Indeed, during this period, a significant majority of real yields in our sample are consistently below the real yield on the Baa-rated corporate bonds, a category of debt that sits at the bottom rung of the investment-grade ladder.

Second, the increase in the cross-sectional dispersion of real interest rates that began in the second half of the 1980s coincided with the deepening of the market for

[1] To mitigate the effect of outliers on the sample statistics, we eliminated all observations with real interest rates in excess of 30 percent per annum.

Figure 1: The Evolution of Real Bond Yields



NOTES: This figure depicts the evolution of the cross-sectional distribution of real bond yields in our sample. The solid black line shows the median of the cross-sectional distribution of real yields, while the shaded green band shows a corresponding measure of cross-sectional dispersion, calculated as the difference between the 95th percentile and the 5th percentile of the distribution. The solid red line shows the real aggregate yield on all Baa-rated corporate bonds. The shaded blue vertical bars denote the NBER-dated recessions.

"junk-rated" corporate debt. The drift of the real Baa yield towards the center of the cross-sectional distribution is another piece of evidence pointing to the increased ability of riskier firms to tap the corporate cash market. The amount of cross-sectional heterogeneity in our sample is particularly apparent between 2000 and 2003, a period in which the effects of a cyclical downturn were compounded by a slew of corporate scandals. This combination of the cross-sectional heterogeneity in real financing costs with considerable cyclical fluctuations are factors that should enhance our ability to identify variation in the investment supply curve and thus help us to estimate more precisely the interest sensitivity of investment demand.

Because our income and balance sheet data are available only at an annual frequency, we converted the monthly bond yields to firm-level interest rates in two steps. First, we calculated an average bond yield for firm i in month t by averaging the yields (both nominal and real) on the firm's outstanding bonds in that month, using market values of bond issues as weights:

$$y_{it} = \sum_{k=1}^{B_{it}} w_{it}^k y_{it}^k \quad \text{and} \quad r_{it} = \sum_{k=1}^{B_{it}} w_{it}^k r_{it}^k,$$

where B_{it} denotes the number of outstanding bond issues of firm i at the end of month t, $0 < w_{it}^k \leq 1$ is the weight for bond issue k, and y_{it}^k and r_{it}^k are the nominal and real yields on bond k, respectively. To convert these firm-level rates to annual frequency, we then averaged the available monthly yields over the twelve months of the firm's fiscal year. For example, for a firm with fiscal year ending in December, the average interest rate in year t is calculated as an unweighted average of the available monthly yields from January through December of the same year. For a firm with fiscal year ending in, say, June, the average interest rate in year t is calculated as an unweighted average of the available monthly yields from July of year $t-1$ through June of year t.

Income and balance sheet data: For 1,192 firms in the U.S. nonfarm nonfinancial corporate sector, we linked these firm-specific average market interest rates on long-term unsecured debt to income and balance sheet items from the annual Compustat data files. To ensure comparability with previous empirical work, we follow Gilchrist and Himmelberg (1998) in the construction of the standard variables (e.g., investment rate, sales-to-capital ratio, Tobin's Q, etc.) used in our analysis. Table 2 contains summary statistics for the key variables in our matched annual panel.[2]

Although our sample focuses on firms that have both equity and a portion of their long-term debt traded in capital markets, firm size—measured by sales or market capitalization—varies widely in our sample. Not surprisingly, though, most of the firms in our data set are quite large. The median firm has annual real sales of about \$3.4 billion and a real market capitalization of more than \$2.6 billion.

Despite the fact that firms in our sample generally have only a few senior unsecured bond issues trading at any given point in time, this publicly-traded debt represents a significant portion of their long-term debt. The ratio of the par value of traded bonds outstanding to the book value of total long-term debt on firms' balance sheet is, on average, almost 0.45, indicating that market prices on these outstanding securities likely provide an accurate gauge of the marginal financing costs. During our sample

[2]Describe the outlier removal criteria.

Table 2: Summary Statistics for Key Variables

Variable	Mean	Std. Dev.	Min	Median	Max
Sales[a] (\$bil.)	8.36	16.78	$< .00$	3.41	245.0
Mkt. Capitalization[b] (\$bil.)	8.27	18.98	$< .00$	2.62	297.7
Par Value to L-T Debt[c]	0.44	0.25	$< .00$	0.41	1.00
Real Interest Rate[d] (%)	5.33	3.01	−2.42	4.93	29.89
Investment to Capital[e]	0.21	0.14	$< .00$	0.18	1.00
Sales to Capital[f]	3.66	3.27	0.13	2.81	24.81
Profits to Capital[g]	0.46	0.36	−2.00	0.37	2.50
Tobin's Q[h]	1.16	0.78	0.02	0.94	15.07

Panel Dimensions

Obs. $= 9,983$ $N = 1,131$ firms

Min. Tenure $= 1$ Median Tenure $= 6$ Max. Tenure $= 32$

NOTES: Sample period: Annual data from 1973 to 2004 ($T = 32$). In variable definitions, $x_n(t)$ denotes the Compustat data item n in period t.

[a]The real value of sales in period t: $x_{12}(t)$ deflated by the CPI.

[b]The real market value of common shares outstanding at the end of period t: $x_{25}(t) \times x_{199}(t)$ deflated by the CPI.

[c]The ratio of the par value of all of the firm's traded bonds to the book value of its total long-term debt ($x_9(t)$).

[d]Annual real yield on the firm's outstanding bonds (see text for details).

[e]The ratio of gross investment in period t to net property, plant, and equipment at the end of period $t-1$: $x_{30}(t)/x_8(t-1)$.

[f]The ratio of (net) sales in period t to net property, plant, and equipment at the end of period $t-1$: $x_{12}(t)/x_8(t-1)$.

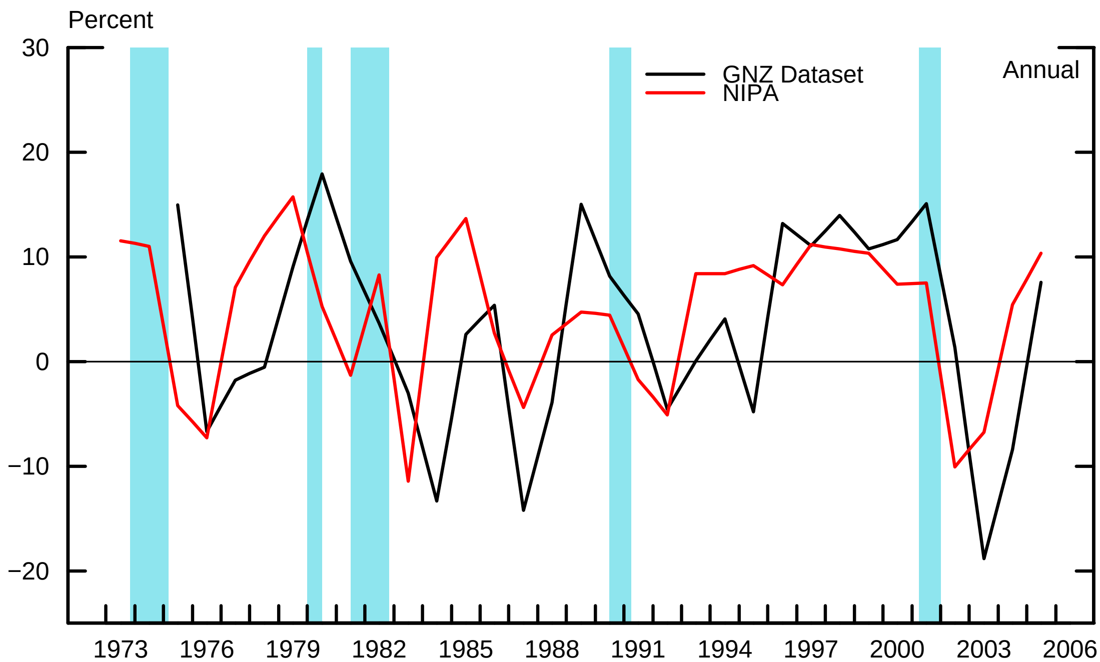
[g]The ratio of operating income (loss) in period t to net property, plant, and equipment at the end of period $t-1$: $x_{13}(t)/x_8(t-1)$.

[h]The ratio of the sum of the market value of common shares outstanding and the book value of total liabilities at the end of period t to the book value of total assets at the end of period t: $[x_{25}(t) \times x_{199}(t) + x_{181}(t)]/x_6(t)$.

period, these financing costs averaged—in real terms—about 5.3 percent and were associated with an average annual investment rate (i.e., investment-to-capital ratio) of 21 percent.

Figure 2 compares the dynamics of investment in our sample with those of the U.S. economy as a whole. While our sample includes less than 1,200 firms, these firms tend to be large and, consequently, their investment pattern in the aggregate is broadly similar to the investment dynamics in the National Income and Product Accounts (NIPA). [To be continued.]

Figure 2: The Growth of Business Fixed Investment



NOTES: The solid black line shows the growth rate of the aggregate real capital expenditures for the firms in our sample. The solid red line shows the growth rate of real business fixed investment measured by the NIPA. Both variables are in chain-weighted (2000=100) dollars. The shaded blue vertical bars denote the NBER-dated recessions.

4 Econometric Methodology and Results

As in conventional models of capital demand, our baseline regression specification emphasizes the role of expected future profitability and financing costs as key determinants of the investment process:

$$\frac{I_{it}}{K_{i,t-1}} = \beta_1' Z_{it} + \beta_2 \mathrm{FC}_{it} + \eta_i + \lambda_{st} + \epsilon_{it}, \tag{1}$$

where $I_{it}/K_{i,t-1}$ denotes the investment to capital ratio for firm i in year t, Z_{it} is a vector of variables capturing firm i's future investment opportunities, and FC_{it} is our firm-specific measure of real financing costs. Unobservable firm-specific time-invariant factors are captured by the fixed firm effect η_i, whereas the sector-specific fixed time effect λ_{st} controls for any aggregate sectoral shocks.[3] The zero-mean random disturbance ϵ_{it} is assumed to be uncorrelated with both Z_{it} and FC_{it}.

4.1 Benchmark Results

In this section, we present our bechmark results. We focus on the entire sample period and estimate equation 1 in levels and log-levels, using both the "within" and first-differencing transformations to eliminate fixed firm effects η_i.

[3]Our ten industrial sectors are based on the 2-digit SIC codes: (1) Mining (SICs 10, 12, 13, and 14); (2) Construction (SICs 15, 16, and 17); (3) Nondurable goods manufacturing (SICs 20, 21, 22, 23, 26, 27, 28, 29, 30, and 31); (4) Durable goods manufacturing (SICs 24, 25, 32, 33, 34, 35, 36, 37, 38, and 39); (5) Transportation (SICs 40, 41, 42, 44, 45, 46, and 47); (6) Communications (SIC 48); (7) Electric, gas, and sanitary services (SIC 49); (8) Wholesale trade (SICs 50 and 51); (9) Retail trade (SICs 52, 53, 54, 55, 56, 57, 58, and 59); and (10) Services (SICs greater than equal to 70, excluding the FIRE sector).

Table 3: Investment and Interest Rates
(Levels Specification)

	Dependent Variable: $I_{it}/K_{i,t-1}$			
Variable	(1)	(2)	(3)	(4)
$S_{it}/K_{i,t-1}$	0.028	0.022	-	-
	(0.003)	(0.003)		
$Q_{i,t-1}$	-	-	0.050	0.035
			(0.007)	(0.006)
$\Pi_{i,t-1}/K_{i,t-2}$	-	0.098	-	0.125
		(0.013)		(0.013)
r_{it}	-0.808	-0.660	-0.799	-0.614
	(0.137)	(0.138)	(0.138)	(0.134)
$\Pr > W_\lambda$[a]	$< .001$	$< .001$	< 0.001	$< .001$
AIC[b]	-1.891	-1.920	-1.844	-1.894
Adj. R^2	0.538	0.551	0.516	0.539
Panel Dimensions				
Sample Period: 1973–2004				
Obs. $= 7,968$	$N = 789$ (firms)	$\overline{T} = 10.1$ (years)		

NOTES: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 4: Investment and Interest Rates
(Differences Specification)

Variable	Dependent Variable: $\Delta(I_{it}/K_{i,t-1})$ (1)	(2)	(3)	(4)
$\Delta(S_{it}/K_{i,t-1})$	0.046	0.047	-	-
	(0.004)	(0.004)		
$\Delta Q_{i,t-1}$	-	-	0.053	0.051
			(0.007)	(0.007)
$\Delta(\Pi_{i,t-1}/K_{i,t-2})$	-	0.047	-	0.026
		(0.011)		(0.011)
Δr_{it}	-0.618	-0.564	-0.682	-0.657
	(0.145)	(0.148)	(0.136)	(0.138)
$\Pr > W_{\Delta\lambda}{}^a$	$< .001$	$< .001$	< 0.001	$< .001$
AIC[b]	-1.731	-1.736	-1.622	-1.623
Adj. R^2	0.197	0.201	0.104	0.105

Panel Dimensions

Sample Period: 1973–2004

Obs. $= 7,012$ $N = 779$ (firms) $\overline{T} = 9.0$ (years)

NOTES: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 5: Investment and Interest Rates
(Log-Levels Specification)

	Dependent Variable: $\ln(I_{it}/K_{i,t-1})$			
Variable	(1)	(2)	(3)	(4)
$\ln(S_{it}/K_{i,t-1})$	0.666	0.549	-	-
	(0.047)	(0.047)		
$\ln Q_{i,t-1}$	-	-	0.683	0.485
			(0.047)	(0.048)
$\ln(1+\Pi_{i,t-1}/K_{i,t-2})$	-	0.865	-	1.054
		(0.089)		(0.912)
$\ln(1+r_{it})$	-5.277	-4.234	-5.368	-4.213
	(0.734)	(0.714)	(0.770)	(0.702)
$\Pr > W_\lambda$ [a]	$< .001$	$< .001$	< 0.001	$< .001$
AIC[b]	1.090	1.046	1.177	1.116
Adj. R^2	0.631	0.647	0.596	0.622

Panel Dimensions

Sample Period: 1973–2004

Obs. $= 7,968$ $N = 789$ (firms) $\overline{T} = 10.1$ (years)

Notes: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 6: Investment and Interest Rates
(Log-Differences Specification)

	Dependent Variable: $\Delta \ln(I_{it}/K_{i,t-1})$			
Variable	(1)	(2)	(3)	(4)
$\Delta \ln(S_{it}/K_{i,t-1})$	0.939	0.961	-	-
	(0.045)	(0.047)		
$\Delta \ln Q_{i,t-1}$	-	-	0.684	0.663
			(0.047)	(0.048)
$\Delta \ln(1 + \Pi_{i,t-1}/K_{i,t-2})$	-	0.584	-	0.232
		(0.065)		(0.078)
$\Delta \ln(1 + r_{it})$	-3.047	-2.451	-3.998	-3.812
	(0.707)	(0.706)	(0.654)	(0.653)
$\Pr > W_{\Delta\lambda}$[a]	$< .001$	$< .001$	< 0.001	$< .001$
AIC[b]	1.050	1.038	1.229	1.227
Adj. R^2	0.276	0.289	0.140	0.142

Panel Dimensions

Sample Period: 1973–2004

Obs. $= 7{,}012$ $N = 779$ (firms) $\overline{T} = 9.0$ (years)

NOTES: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

5 Default Risk

In this section, we focus on part of the sample with a fully formed market for lower-quality corporate debt. Firm-specific interest interest rates are influenced importantly by likelihood of default. Since 1991, we have firm-specific measures of expected default risk, which allows us to control for default risk in our investment regressions. Starting in 1991, our sample also includes a firm-specific probability of default.

Our measure of the probability that a firm will default within a certain period of time comes from the Moody's/KMV Corporation (MKMV). The theoretical underpinnings for these probabilities of default are provided by the seminal work of Merton (1973, 1974). According to this option-theoretic approach, the probability that a firm will default on its debt obligations at any point in the future is determined by three major factors: the market value of the firm's assets, the standard deviation of the stochastic process for the market value of assets (i.e., asset volatility), and the firm's leverage. These three factors are combined into a single measure of default risk called *distance to default*, defined as

$$\begin{bmatrix}\text{Distance}\\ \text{to Default}\end{bmatrix} = \frac{\begin{bmatrix}\text{Mkt. Value}\\ \text{of Assets}\end{bmatrix} - \begin{bmatrix}\text{Default}\\ \text{Point}\end{bmatrix}}{\begin{bmatrix}\text{Mkt. Value}\\ \text{of Assets}\end{bmatrix} \times \begin{bmatrix}\text{Asset}\\ \text{Volatility}\end{bmatrix}}.$$

In theory, the default point should equal to the book value of total liabilities, implying that the distance to default compares the net worth of the firm with the size of a one-standard-deviation move in the firm's asset value.[4] The market value of assets and the volatility of assets, however, are not directly observable, so they have to be computed in order to calculate the distance to default. Assuming that the firm's assets are traded, the market value of the firm's equity can be viewed as a call option on the firm's assets with the strike price equal to the current book value of the firm's total debt.[5] Using this insight, MKMV "backs out" the market value and the volatility of assets from a proprietary variant of the Black-Scholes-Merton option

[4]Empirically, however, MKMV has found that most defaults occur when the market value of the firm's assets drops to the value equal to the sum of the firm's current liabilities and one-half of long-term liabilities (i.e., Default Point = Current Liabilities + 0.5 × Long-Term Liabilities), and the default point is calibrated accordingly.

[5]The assumption that all of the firm's assets are traded is clearly inappropriate in most cases. Nevertheless, as shown by Ericsson and Reneby (2004), this approach is still valid provided that at least one of the firm's securities (e.g., equity) is traded.

pricing model, employing the observed book value of liabilities and the market value of equity as inputs; see Crosbie and Bohn (2003) for details.

In the final step, MKMV transforms the distance to default into an expected probability of default—the so-called expected default frequency (EDF)—using an empirical distribution of actual defaults. Specifically, MKMV estimates a mapping relating the likelihood of default over a particular horizon to various levels of distance to default, employing an extensive proprietary database of historical defaults and bankruptcies in the United States.[6] These EDFs are calculated monthly and in our case measure the probability that a firm will default on its debt obligations over the subsequent 12 months. We used EDFs as of the last month of the firm's fiscal year when merging MKMV data to the annual Compustat data files.

It should be noted that MKMV does not disclose how the mapping between the distance to default and the EDF is computed. However, these timely, forward-looking measures of default risk are widely used by financial market participants when assessing credit risk. One clear advantage of EDFs over the traditional measures of default risk based, for example, on credit ratings stems from the fact that the dynamics of EDFs are driven primarily by the movements in equity values. As a result, EDF-based measures of credit risk have the ability to react more rapidly to deterioration in the firm's credit quality as well as to reflect more promptly changes in aggregate economic conditions.

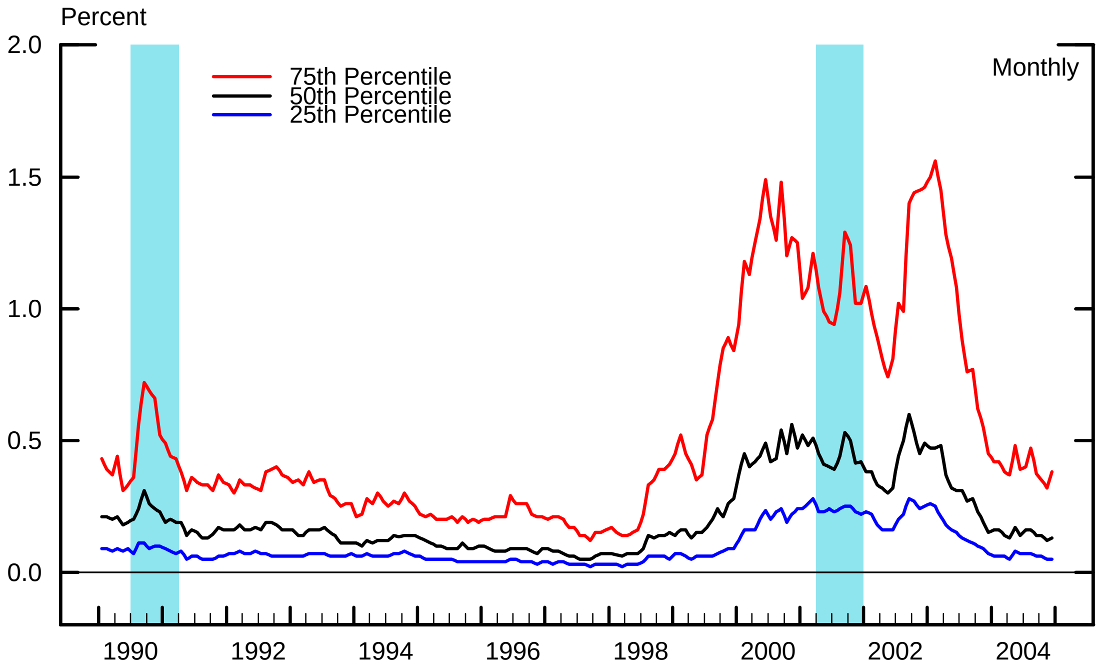
Figure 3 depicts the evolution of the cross-sectional distribution of the expected year-ahead default frequencies for the firms in our sample.

We now augment our baseline specification with a firm-specific measure of default risk:

$$\frac{I_{it}}{K_{i,t-1}} = \beta_1' Z_{it} + \beta_2 \mathrm{EDF}_{i,t-1} + \beta_3 \mathrm{FC}_{it} + \eta_i + \lambda_{st} + \epsilon_{it}, \tag{2}$$

[6]The MKMV's mapping of distances to default to EDFs restricts the probability estimates to the range between 0.02 percent and 20 percent because of sparse data beyond these points.

Figure 3: The Evolution of Year-Ahead Expected Default Frequencies



NOTES: This figure depicts the time-series of the 25th, 50th, and 75th percentile of the cross-sectional distribution of year-ahead expected defaults frequencies (EDFs) for the firms in our sample. The shaded blue vertical bars denote the NBER-dated recessions.

Table 7: Investment, Interest Rates, and Default Risk
(Levels Specification)

	Dependent Variable: $I_{it}/K_{i,t-1}$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$S_{it}/K_{i,t-1}$	0.030	0.030	0.026	-	-	-
	(0.003)	(0.003)	(0.003)			
$Q_{i,t-1}$	-	-	-	0.044	0.043	0.034
				(0.007)	(0.007)	(0.007)
$\text{EDF}_{i,t-1}$	-	-0.366	-0.328	-	-0.368	-0.323
		(0.113)	(0.115)		(0.121)	(0.121)
$\Pi_{i,t-1}/K_{i,t-2}$	-	-	0.078	-	-	0.096
			(0.015)			(0.015)
r_{it}	-0.646	-0.433	-0.348	-0.699	-0.485	-0.378
	(0.153)	(0.167)	(0.171)	(0.152)	(0.169)	(0.171)
$\Pr > W_{\lambda}$[a]	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	-2.167	-2.174	-2.199	-2.108	-2.115	-2.151
Adj. R^2	0.606	0.609	0.618	0.582	0.585	0.600

Panel Dimensions

Sample Period: 1991–2004

Obs. $= 4,819$ $N = 718$ (firms) $\overline{T} = 6.7$ (years)

NOTES: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 8: Investment, Interest Rates, and Default Risk
(Differences Specification)

	Dependent Variable: $\Delta(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta(S_{it}/K_{i,t-1})$	0.037	0.037	0.037	-	-	-
	(0.004)	(0.004)	(0.004)			
$\Delta Q_{i,t-1}$	-	-	-	0.047	0.046	0.046
				(0.005)	(0.006)	(0.006)
$\Delta\text{EDF}_{i,t-1}$	-	−0.261	−0.247	-	−0.238	−0.238
		(0.096)	(0.097)		(0.096)	(0.098)
$\Delta(\Pi_{i,t-1}/K_{i,t-2})$	-	-	0.028	-	-	0.001
			(0.013)			(0.012)
Δr_{it}	−0.610	−0.528	−0.500	−0.645	−0.572	−0.571
	(0.164)	(0.163)	(0.165)	(0.156)	(0.156)	(0.157)
$\Pr > W_{\Delta\lambda}$[a]	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	−2.043	−2.047	−2.050	−1.957	−1.960	−1.959
Adj. R^2	0.210	0.214	0.216	0.139	0.142	0.142

Panel Dimensions

Sample Period: 1991–2004

Obs. $= 3,993$ $N = 709$ (firms) $\overline{T} = 5.6$ (years)

NOTES: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 9: Investment, Interest Rates, and Default Risk
(Log-Levels Specification)

	Dependent Variable: $\ln(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(S_{it}/K_{i,t-1})$	0.715	0.706	0.632	-	-	-
	(0.049)	(0.051)	(0.051)			
$\ln Q_{i,t-1}$	-	-	-	0.691	0.657	0.516
				(0.058)	(0.057)	(0.059)
$\ln(1+\text{EDF}_{i,t-1})$	-	-3.489	-3.104	-	-2.992	-2.675
		(0.614)	(0.613)		(0.716)	(0.688)
$\ln(1+\Pi_{i,t-1}/K_{i,t-2})$	-	-	0.776	-	-	0.910
			(0.113)			(0.117)
$\ln(1+r_{it})$	-4.679	-2.553	-1.901	-4.950	-3.201	-2.465
	(0.806)	(0.796)	(0.787)	(0.849)	(0.849)	(0.814)
$\Pr > W_\lambda{}^a$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC^b	0.960	0.935	0.897	1.074	1.059	1.014
Adj. R^2	0.683	0.691	0.703	0.645	0.650	0.666

Panel Dimensions

Sample Period: 1991–2004

Obs. $= 4,819$ $N = 718$ (firms) $\overline{T} = 6.7$ (years)

NOTES: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 10: Investment, Interest Rates, and Default Risk
(Log-Differences Specification)

	Dependent Variable: $\Delta \ln(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(S_{it}/K_{i,t-1})$	0.813	0.813	0.832	-	-	-
	(0.046)	(0.046)	(0.048)			
$\Delta \ln Q_{i,t-1}$	-	-	-	0.661	0.623	0.620
				(0.054)	(0.055)	(0.056)
$\Delta \ln(1 + \mathrm{EDF}_{i,t-1})$	-	-2.685	-2.498	-	-1.694	-1.674
		(0.514)	(0.525)		(0.518)	(0.521)
$\Delta \ln(1 + \Pi_{i,t-1}/K_{i,t-2})$	-	-	0.399	-	-	0.051
			(0.083)			(0.089)
$\Delta \ln(1 + r_{it})$	-3.298	-2.383	-2.032	-3.997	-3.492	-3.456
	(0.765)	(0.754)	(0.762)	(0.714)	(0.713)	(0.713)
$\Pr > W_{\Delta\lambda}$ [a]	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	0.9947	0.926	0.916	1.111	1.105	1.105
Adj. R^2	0.273	0.288	0.296	0.144	0.149	0.149

Panel Dimensions

Sample Period: 1992–2004

Obs. $= 3,993$ $N = 709$ (firms) $\overline{T} = 5.6$ (years)

NOTES: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

6 User Cost of Capital

The incentive to purchase physical capital depends not only on the financial costs, but also on the price of investment goods relative to the price of output, the rate at which capital depreciates, any expected gains or losses associated with capital purchases, and the tax treatment of both the capital purchase and the capital income. These factors were summarized in the user cost of capital by the seminal work of Hall and Jorgenson (1967). We use our firm-level interest rates and industry-level (2-digit SIC) information on the remaining variables to construct the user cost of capital for firm i in period t, C_{it}^{K}, according to

$$C_{it}^{K} = \frac{P_{jt}^{K}}{P_{jt}^{Q}} \left[(1-\tau_t) y_{it} + \delta_{jt} - E_t \left(\frac{\Delta P_{j,t+1}^{K}}{P_{jt}^{K}} \right) \right] \left[\frac{1 - \mathrm{ITC}_t - \tau_t z_{jt}}{1-\tau_t} \right],$$

where P_{jt}^{K}/P_{jt}^{Q} denotes the price of capital goods relative to price of output in industry j, δ_{jt} is the industry-level (time-varying) rate of capital depreciation, $E_t(\Delta P_{j,t+1}^{K}/P_{jt}^{K})$ denotes any expected capital gains associated with the capital purchase, ITC_t is the tax credit rate allowed on investment expenditures, τ_t is the corporate tax rate faced by firm i in period t, and z_{jt} is the present value of the depreciation deduction for industry j that can be subtracted from income for tax purposes. The component of the user cost that varies across firms is the post-tax nominal interest rate (interest being tax deductible) $(1-\tau_t)y_{it}$, where y_{it} is the average yield on firm i's bonds in period t.

Table 11: Investment and User Cost of Capital
(Levels Specification)

	Dependent Variable: $I_{it}/K_{i,t-1}$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$S_{it}/K_{i,t-1}$	0.032	0.031	0.026	-	-	-
	(0.003)	(0.003)	(0.003)			
$Q_{i,t-1}$	-	-	-	0.046	0.044	0.034
				(0.007)	(0.007)	(0.007)
$\text{EDF}_{i,t-1}$	-	-0.493	-0.425	-	-0.517	-0.434
		(0.109)	(0.109)		(0.113)	(0.111)
$\Pi_{i,t-1}/K_{i,t-2}$	-	-	0.081	-	-	0.099
			(0.015)			(0.015)
C_{it}^{K}	-0.205	-0.109	-0.095	-0.201	-0.101	-0.087
	(0.089)	(0.084)	(0.081)	(0.096)	(0.090)	(0.083)
$\Pr > W_{\lambda}{}^{a}$	$<.001$	$<.001$	$<.001$	$<.001$	$<.001$	$<.001$
AIC[b]	-2.153	-2.169	-2.195	-2.092	-2.108	-2.147
Adj. R^2	0.600	0.607	0.617	0.575	0.528	0.598

Panel Dimensions

Sample Period: 1991–2004

Obs. $= 4,819$ $N = 718$ (firms) $\overline{T} = 6.7$ (years)

NOTES: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 12: Investment and User Cost of Capital
(Log-Levels Specification)

	Dependent Variable: $\ln(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\ln(S_{it}/K_{i,t-1})$	0.758	0.723	0.642	-	-	-
	(0.048)	(0.051)	(0.051)			
$\ln Q_{i,t-1}$	-	-	-	0.766	0.685	0.531
				(0.062)	(0.058)	(0.059)
$\ln(1 + \mathrm{EDF}_{i,t-1})$	-	-4.307	-3.649	-	-4.042	-3.429
		(0.618)	(0.602)		(0.697)	(0.647)
$\ln(1 + \Pi_{i,t-1}/K_{i,t-2})$	-	-	0.807	-	-	0.952
			(0.112)			(0.119)
$\ln C^K_{it}$	-0.157	-0.070	-0.067	-0.137	-0.059	-0.059
	(0.068)	(0.058)	(0.053)	(0.074)	(0.063)	(0.056)
$\Pr > W_\lambda$ [a]	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	0.988	0.942	0.900	1..104	1.069	1.020
Adj. R^2	0.674	0.689	0.702	0.634	0.647	0.664

Panel Dimensions

Sample Period: 1991–2004

Obs. $= 4,819$ $N = 718$ (firms) $\overline{T} = 6.7$ (years)

NOTES: All specifications include fixed firm effects (η_i), fixed sector-specific time effects (λ_{st}), and are estimated using OLS. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

6.1 Measurement Error

One possibility for the statistically insignificant response of investment demand to user cost of capital may be due to attenuation bias reflecting measurement error in the user cost variable. While bond-level data likely provide an accurate gauge of the firm-specific financial costs, the remaining components of the user cost are, at best, measured at the industry level and, consequently, may not accurately reflect the firm-specific incentives for investment expenditures.

Table 13: Investment and (mismeasured) User Cost of Capital (Differences Specification)

	Dependent Variable: $\Delta(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta(S_{it}/K_{i,t-1})$	0.037	0.037	0.037	-	-	-
	(0.004)	(0.004)	(0.004)			
$\Delta Q_{i,t-1}$	-	-	-	0.047	0.046	0.046
				(0.006)	(0.006)	(0.006)
$\Delta \text{EDF}_{i,t-1}$	-	-0.255	-0.240	-	-0.232	-0.232
		(0.097)	(0.099)		(0.097)	(0.099)
$\Delta(\Pi_{i,t-1}/K_{i,t-2})$	-	-	0.028	-	-	0.002
			(0.013)			(0.012)
ΔC^K_{it}	-0.731	-0.635	-0.601	-0.768	-0.683	-0.681
	(0.202)	(0.200)	(0.203)	(0.190)	(0.190)	(0.191)
$\Pr > W_{\Delta\lambda}{}^a$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	-2.033	-2.040	-2.043	-1.948	-1.953	-1.953

Panel Dimensions

Sample Period: 1992–2004

Obs. $= 3,993$ $N = 709$ (firms) $\overline{T} = 5.6$ (years)

Notes: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using 2SLS. The first difference of the user cost of capital ΔC^K_{it} is instrumented with a current and a lagged level of the firm-specific nominal interest rate. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

Table 14: Investment and (mismeasured) User Cost of Capital
(Log-Differences Specification)

	Dependent Variable: $\Delta \ln(I_{it}/K_{i,t-1})$					
Variable	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta \ln(S_{it}/K_{i,t-1})$	0.794	0.800	0.820	-	-	-
	(0.048)	(0.047)	(0.049)			
$\Delta \ln Q_{i,t-1}$	-	-	-	0.649	0.612	0.609
				(0.055)	(0.055)	(0.056)
$\Delta \ln(1 + \text{EDF}_{i,t-1})$	-	-2.646	-2.460	-	-1.668	-1.646
		(0.514)	(0.525)		(0.517)	(0.521)
$\Delta \ln(1 + \Pi_{i,t-1}/K_{i,t-2})$	-	-	0.397	-	-	0.057
			(0.083)			(0.090)
$\Delta \ln C^K_{it}$	-0.756	-0.552	-0.479	-0.898	-0.785	-0.777
	(0.175)	(0.171)	(0.171)	(0.156)	(0.157)	(0.157)
$\Pr > W_{\Delta\lambda}$ [a]	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$	$< .001$
AIC[b]	0.974	0.949	0.927	1.135	1.122	1.122

Panel Dimensions

Sample Period: 1992–2004

Obs. $= 3,993$ $N = 709$ (firms) $\overline{T} = 5.6$ (years)

NOTES: All specifications include the first difference of fixed sector-specific time effects ($\Delta\lambda_{st}$) and are estimated using 2SLS. The first difference of the log of the user cost of capital $\Delta \ln C^K_{it}$ is instrumented with a current and a lagged level of the firm-specific nominal interest rate. Heteroscedasticity- and autocorrelation-consistent asymptotic standard errors are computed according to Arellano (1987) and are reported in parentheses.

[a] p-value for the robust Wald test of the absence of fixed sector-specific time effects.

[b] Akaike Information Criterion (smaller is better).

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