IMF Working Paper

Leverage Shocks: Firm-Level Evidence on Debt Overhang and Investment

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INTERNATIONAL MONETARY FUND

IMF Working Paper

Western Hemisphere Department

Leverage Shocks: Firm-Level Evidence on Debt Overhang and Investment

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December 2020

Abstract

The global economy is in the midst of an unprecedented slump caused by the coronavirus pandemic. This systemic risk like no other at a time of record-breaking debt levels, especially among nonfinancial firms across the world, could exacerbate corporate vulnerabilities, deepen macro-financial instability, and cause long-lasting damage to economic potential. Using data on more than 2.8 million nonfinancial firms from 52 countries during the period 1997–2018, we develop a two-pronged approach to investigate the relationship between corporate leverage and fixed investment spending. The empirical analysis, robust to a battery of sensitivity checks, confirm corporate leverage is highly vulnerable to disruptions in profitability and cash flow at the firm level and economic growth at the aggregate level. These findings imply that corporate debt overhang could become a strenuous burden on nonfinancial firms, especially if the COVID-19 pandemic lingers and global downturn becomes protracted.

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[1] The author would like to thank Nina Biljanovska and Martin Čihák for insightful comments and suggestions. The views expressed herein are those of the authors and should not be attributed to the IMF, its Executive Board, or its management.

Contents   **Page**

Figures

Tables

I. INTRODUCTION

The COVID-19 pandemic is an unprecedented global shock with far-reaching economic and financial repercussions throughout the world.[2] According to the International Monetary Fund (IMF), global real GDP growth is projected to contract by 4.4 percent in 2020, resulting in a cumulative loss of more than US$10 trillion over 2020-21. The synchronized nature of the downturn—driven by massive disruptions in supply networks and a collapse in private-sector demand—jeopardizes corporate profitability and depletes firms' cash buffers. At the same time, while governments and central banks have responded by providing extensive fiscal stimulus, lowering interest rates and relaxing macroprudential regulations, uncertainty surrounding the pandemic has depressed risk appetite and pushed borrowing costs higher. This is a systemic risk like no other at a time of record-breaking debt levels, especially among nonfinancial firms across the world. While nonfinancial corporate leverage has remained high at an average of about 90 percent of GDP in advanced economies, it surged in developing countries from 56 percent of GDP in 2008 to 96 percent in 2018 (Figure 1). Consequently, a vicious cycle triggered by the pandemic could exacerbate corporate vulnerabilities, deepen macro-financial instability, and cause long-lasting damage to economic potential (Cevik and Miryugin, 2020). Firms with high leverage are particularly vulnerable to higher borrowing costs and reductions in the cash flow that could lead to a surge of corporate defaults and discourage future investment.

Figure 1. Uncertainty and Non-financial Corporate Debt
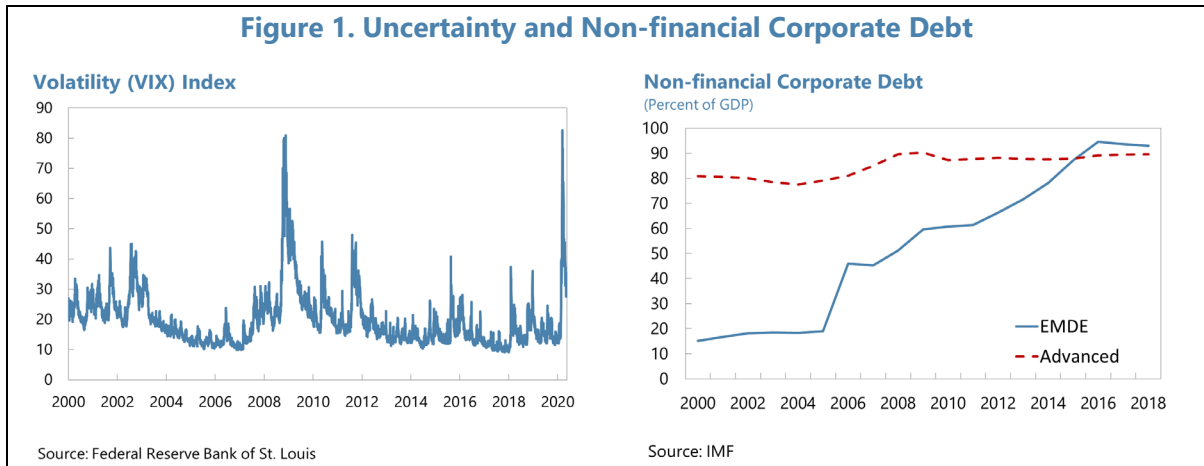
There is extensive literature on the determinants of corporate leverage and investment dynamics, emphasizing the role of firm- and sector-specific factors such as firm size, profitability, asset tangibility, and industry median leverage (Myers, 1984; Titman and Wessels, 1988; Harris and Raviv, 1991; Booth and others, 2001; Baker and Wurgler, 2002; Lemmon, Roberts, and Zender, 2008; Frank and Goyal, 2009; Gungoraydinoglu and Öztekin, 2011; Graham, Leary, and Roberts, 2015; De Angelo and Roll, 2015; Öztekin, 2015). On the other hand, Borio (1990), Rajan and Zingales (1995), Kayo and Kimura (2011) and Cevik and Miryugin (2018) underscore the critical

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[2] As of December 10, 2020, there are over 69.5 million confirmed cases of COVID-19 in 190 countries, with more than 1.5 million deaths. The latest figures can be found at John Hopkins University's Center for Systems Science and Engineering:https://www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6.

role of country-specific macroeconomic and institutional factors. More recently, favorable global economic and financial conditions are shown to have contributed to corporate leverage by easing borrowing constraints (Bekaert, Hoerova, and Lo Duca, 2013; IMF, 2015; Cerutti, Claessens, and Puy, 2015; Feyen and others, 2015; Alter and Elekdag, 2020). With regards to the impact of corporate leverage on fixed investment, there is no consensus in the literature, with conflicting evidence on potentially positive and negative effects of debt on capital spending. On the positive side, debt financing is shown to provide tax advantages compared to other forms of financing and lower agency costs between managers and shareholders (Modigliani and Miller, 1963; Ross, 1977; Grossman and Hart, 1982). On the negative side, high levels of corporate debt is found to inhibit fixed investment by increasing payments and thereby constraining to access to finance and lowering available funds for investment (Lang, Ofek, and Stulz, 1997; Cecchetti, Mohanty, and Zampolli, 2011; Borensztein and Ye, 2018; Cevik and Miryugin, 2018; Kalemli-Özcan, Laeven, and Moreno, 2019).

This paper contributes to the literature by investigating the link between corporate leverage and investment spending at the firm-level through a two-pronged approach and using a large dataset of more than 1.8 million nonfinancial firms from 52 countries over the period 1997–2018. First, we examine the determinants of corporate leverage as measured by the total debt-to-assets ratio, taking into account country-specific characteristics; second, in view of the emerging macro-financial fault lines across the world, we explore whether corporate debt overhang can become an impediment to investment growth. The empirical results, robust to a battery of sensitivity checks, confirm nonfinancial corporate leverage is highly vulnerable to disruptions in profitability and cash flow at the firm level and economic growth at the aggregate level. These findings imply that corporate debt overhang could become a strenuous burden on nonfinancial firms during severe economic downturns. In the second stage of our firm-level empirical inquiry, we further document that highly leveraged companies tend to have lower levels of fixed investment. For example, a manufacturing firm with a leverage ratio of 100 percent invests about 4 percentage points less than a company with a debt-to-asset ratio of 50 percent in the same sector. In times of greater macro-financial uncertainty, corporate debt overhang is likely to depress nonfinancial capital investment for years to come, especially if the COVID-19 pandemic lingers and global downturn becomes protracted.

The remainder of this study is organized as follows. Section II provides an overview of the dataset used in the analysis. Section III introduces the salient features of our econometric strategy. Section IV presents the empirical results, including a series of robustness checks. Finally, Section V offers concluding remarks with policy implications.

II. DATA OVERVIEW

We obtain harmonized firm-level financial data, including balance sheets and income statements, on 1,867,227 nonfinancial firms in 52 countries during the period 1997–2018.[3] Unlike other administrative firm-level databases, Orbis provides a comparable coverage of both public (listed)

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[3] All values reported in the Orbis database are in nominal US dollars.

and private (non-listed) firms including small and medium-sized enterprises in advanced and developing countries. The complete Orbis sample consists of more than 200 million firm annual observations from over 100 countries around the world. However, similar to any other large-scale micro dataset, the Orbis data require careful management to ensure consistency and comparability across firms and countries and over time. First, we select countries with sufficient number of observations by setting a threshold of 10,000 annual observations per country. Second, following the data cleaning principles suggested by Gal (2013) and Kalemli-Özcan and others (2015), we drop observations where total assets, tangible fixed assets, employment, operating revenue, sales and short-term loans and long-term debt in any given year are missing or negative, and where total assets do not equal to total liabilities and equity. Third, we winsorize the firm-level variables at the 1th and 99th percentile of the distribution in order to minimize the effect of possibly spurious outliers.[4] After these steps, we obtain an unbalanced panel of 1,867,227 unique firms from 52 countries (30 advanced and 22 developing) with a total of 10,426,274 firm-year observations during the period 1997–2018.[5]

Table 1. Sectoral Distribution of Firms

Sector	Num. of obs.	Percent
Agriculture	377,802	2.60%
Mining	56,536	0.39%
Manufacturing	3,102,690	21.35%
Utilities	234,161	1.61%
Construction	2,028,255	13.96%
IT	439,603	3.02%
Other service activities, households, extraterritorial bodies	766,552	5.27%
Wholesale and retail trade, accommodation	4,330,233	29.79%
Transport and storage	649,077	4.47%
Real estate	1,112,347	7.65%
Professional and administrative activities	1,436,389	9.88%
Total	*14,533,645*	*100%*

Table 1 displays the distribution of nonfinancial firms across 52 countries and 10 nonfinancial sectors grouped according to the statistical classification of economic activities based on the *Nomenclature des Activités Économiques dans la Communauté Européenne* (NACE). The majority is concentrated in Europe, accounting for 87 percent of nonfinancial firms covered in our sample. It is important to note that the number of firms covered in the Orbis database varies from one year to another, increasing considerably after 2000 (Appendix Table A1). In terms of sectoral coverage, the dataset is based on the NACE classification of economic activities and covers nonfinancial sectors excluding agriculture, public administration and defense, activities of

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[4] The estimation results remain robust if we winsorize 5 percent of observations on both tails of the distribution. These results are available upon request.

[5] The list of countries in our sample and the numbers of firms and firm-year observations per country are provided Appendix Table A3. Countries are classified as advanced economies, and emerging market and developing economies according to the IMF's World Economic Outlook (WEO) database.

extraterritorial organizations and bodies, and activities of households as employers and for own use. Most of the firms in the sample operate in the retail and wholesale trade sector, accounting for about 30 percent of observations, followed by manufacturing with 21 percent, construction with 14 percent, and administrative and professional activities with 10 percent.

Descriptive statistics of all variables for the entire sample as well as subgroups of advanced and developing countries are presented in Appendix Table A3. Our dependent variables are (1) corporate leverage (defined as short-term and long-term debt over total assets) and (2) fixed investment (measured by the difference between tangible assets in the current period and those in the previous period scaled by total assets at the end of the previous year). We include several key firm characteristics, such as firm age (measured by the log of years since establishment), firm size (measured as the log of total assets), profitability (measured by the ratio of profit before tax to total assets), cash flow (measured by the ratio of cash flow to total assets), sales growth (measured by the rate of change in sales), asset tangibility (measured by tangible fixed assets to total assets), and effective interest rate (measured by the ratio of interest payment in the current period to total debt at the end of the previous year).

Figure 2. Corporate Leverage and Fixed Investment

Source: Orbis; authors' calculations.
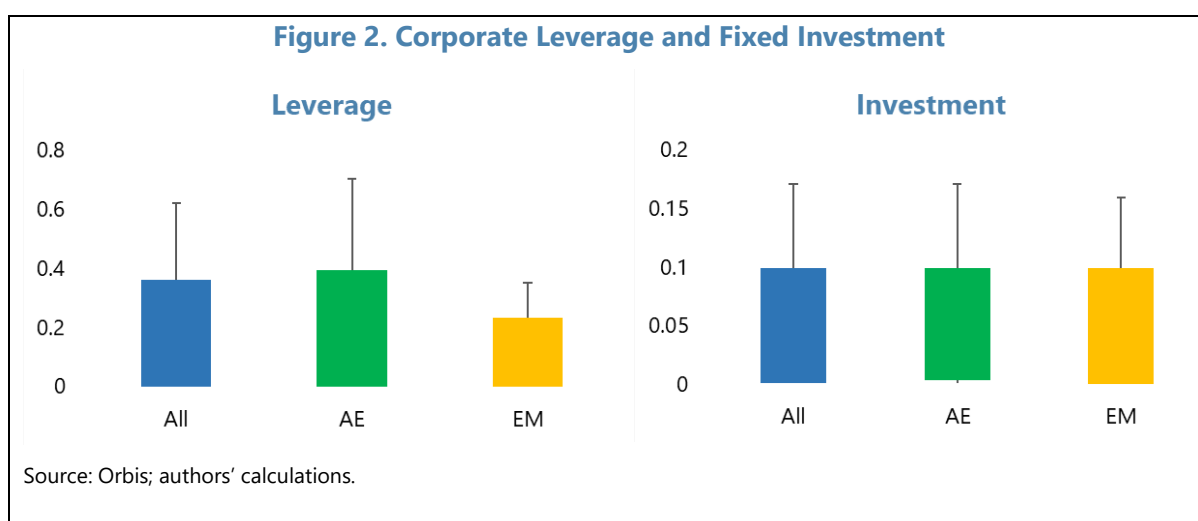
Firm-level data extend over a long period, covering economic booms and downturns. While this coverage of different stages of the business cycle enriches the empirical analysis, it also necessitates the inclusion of country-specific information (real GDP per capita, real GDP growth, trade openness measured by the sum of exports and imports in GDP, financial development measured by domestic credit to the private sector as a share of GDP, and measures of institutional quality) as control variables. These economic and financial statistics are drawn from the IMF's World Economic Outlook (WEO) database and the World Bank's World Development Indicators (WDI) database.

There are large variations in the corporate leverage and fixed investment ratios and firm characteristics used in the analysis across sectors and type of firms, as well as in macroeconomic and financial conditions and measures of institutional quality across countries and over time. It is essential to analyze the time-series properties of the data to avoid spurious results by conducting panel unit root tests. We check the stationarity of all variables by applying the Im-

Pesaran-Shin (2003) procedure, which is widely used in the empirical literature to conduct a panel unit root test. The results, available upon request, indicate that the variables used in the analysis are stationary after logarithmic transformation or upon first differencing.

Figure 3. Distribution of Firm-level Characteristics

Source: Orbis; authors' calculations.
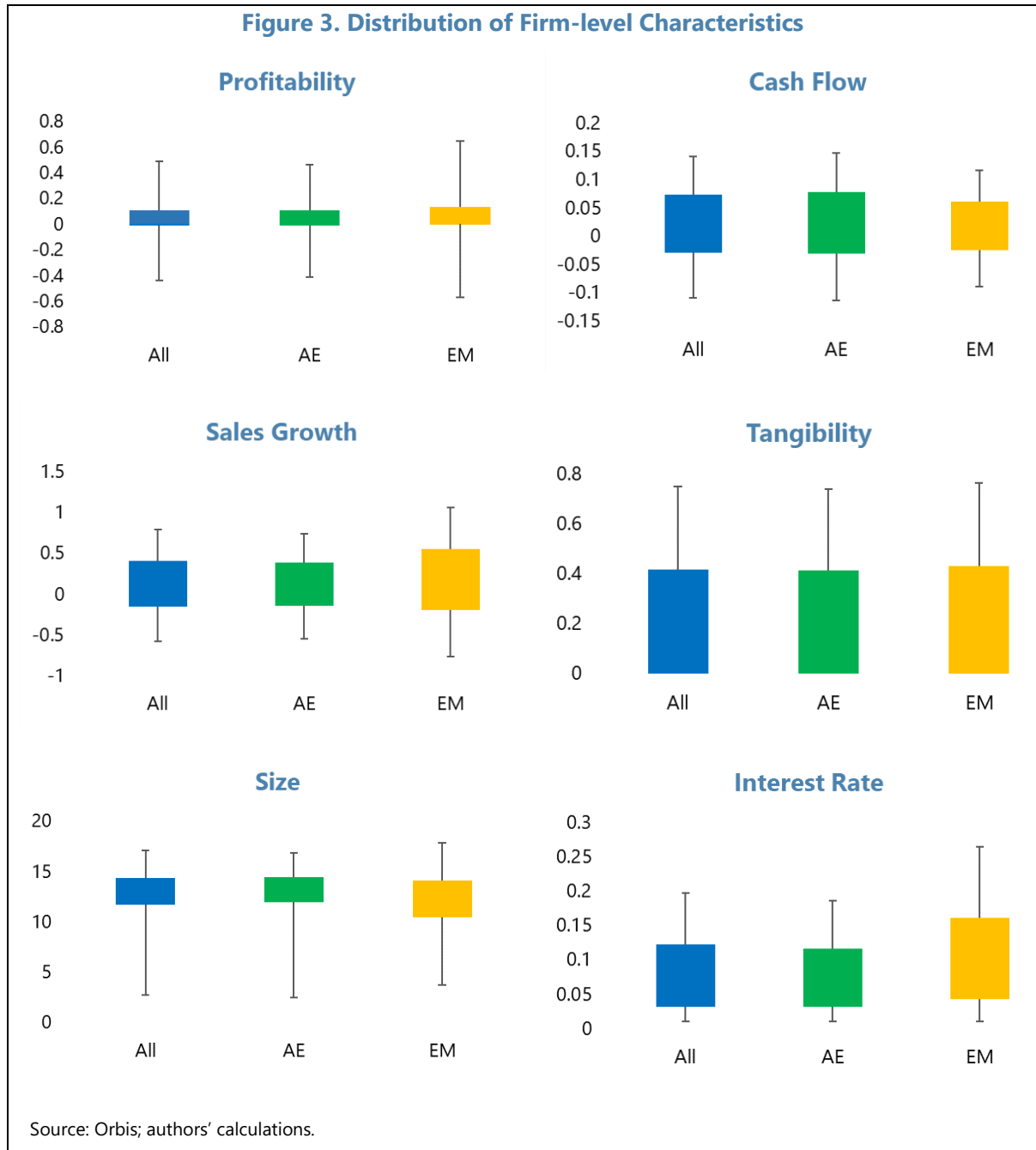
III. EMPIRICAL METHODOLOGY

Our baseline models of corporate leverage and investment build on standard empirical models with macro-financial factors, similar to those used Giroud and Mueller (2017), Cevik and Miryugin (2018), and Kalemli-Özcan, Laeven, and Moreno (2019). In the first stage of our empirical analysis, we focus on the determinants of corporate leverage according to the following specification:

$$Lev_{isct} = \alpha_1 Firm_{isct-1} + \alpha_2 Macro_{ct} + \eta_i + \eta_{st} + \eta_{cs} + \varepsilon_{isct} \quad (1)$$

in which the subscripts *i*, *s*, *c*, and *t* denote firm, sector, country, and time, respectively. The dependent variable, *Lev*, corporate leverage as measured by the ratio of total debt to total assets. The term *Firm* is a vector of company-specific control variables, including total assets, profitability, cash flow, sales growth, asset tangibility, effective interest rate, and firm age. The term *Macro* denotes a set of country-specific and global factors, including real GDP per capita, real GDP growth, trade openness, and financial development.[6]

In the second stage, we investigate the link between corporate leverage and fixed investment spending at the firm level according to the following specification:

$$Inv_{isct} = \beta_1 Lev_{isct-1} + \beta_2 Firm_{isct-1} + \beta_3 Macro_{ct} + \eta_i + \eta_{st} + \eta_{cs} + \varepsilon_{isct} \quad (2)$$

in which the dependent variable, *Inv*, denotes the ratio of net fixed investment in a given year to total assets at the beginning of the year.[7] *Lev* becomes our main explanatory variable of interest, standing for corporate leverage as measured by the ratio of total debt to total assets. We include the same set of firm characteristics and macroeconomic variables as above in the terms *Firm* and *Macro*, respectively.

In both models, the η_i coefficient denotes the firm-specific fixed effects capturing time-invariant unobservable factors. The η_{st} coefficient denotes the set of sector-year fixed effects capturing unobserved time-invariant heterogeneity among firms across sectors, and common shocks to firms belonging to the same sector in a given year. This helps control for aggregate and sectoral demand or policy-induced shocks, as well as cross-sectional dependence among firms in our sample. Furthermore, including sector-year fixed effects allows us to interpret the coefficient on, for example, the leverage ratio as the effect of higher indebtedness relative to a firm's sector peers at time *t*. This is an important consideration since some sectors are more highly leveraged than others, with differing investment patterns. The η_{cs} coefficient does the same for country-sector groups. As a result, without sector-country and sector-year fixed effects, the results would only reflect average investment patterns in more leveraged sectors. Finally, ε_{isct} is an idiosyncratic error term that satisfies the standard assumptions of zero mean and constant variance. Robust standard errors are clustered at the firm level to account for the fact that observations pertaining to a firm are correlated and thus do not contain as much information as unclustered errors.

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[6] As part of our robustness checks, we also include measures of institutional quality (corruption and the rule of law) that are found in the literature to matter for business environment.

[7] Capital spending can be measured on a net or gross basis. The net investment rate is a better indicator than gross investment, as it gauges the change in a firm's stock of physical capital, excluding the fraction of capital that depreciates each year.

IV. ESTIMATION RESULTS

The rich dataset—covering more than 1.8 million nonfinancial firms from 52 countries during the period 1997–2018 with a total of 10.4 million firm-year observations—provides for a comprehensive and robust empirical analysis. All specifications include firm, sector, country and time fixed effects to capture common shocks and unobserved time-invariant heterogeneity among firms across sectors and countries. Estimation results present a consistent picture across different specifications and econometric methodologies. It is also worth noting that the introduction of country-specific macroeconomic control variables does not materially alter the magnitude and statistical significance of estimated coefficients on firm-level variables. These specifications with country-level macroeconomic variables allow us to tease out additional information on the interaction between macroeconomic dynamics and firms' behavior in terms of debt accumulation and fixed investment spending.

A. Determinants of Corporate Leverage

Table 2 presents the baseline estimation results for corporate leverage. As expected, the ratio of total debt to total assets—our measure of leverage—is positively related to firm size and asset tangibility, and negatively related to profitability, cash flow, sales growth, effective interest rate, and firm age. The estimated coefficients for firm-level variables are statistically significant across all specifications for the whole sample as well as subsamples of advanced and emerging market economies. Both profitability and cash flow are found to have a dampening effect on corporate leverage across all country groups and model specifications. However, the impact of profitability appears to be marginally greater in developing countries, whereas the impact of cash flow is twice as much in advanced economies. Sales growth—a common proxy for growth opportunities—has a similar negative and significant effect across all countries, which may reflect the underinvestment problem reported in the literature (Myers, 1977). But this is not the case for emerging market economies, where sales growth is associated with higher leverage.

Both firm size and asset tangibility, on the other hand, have a positive impact on leverage. That is, larger firms and firms with more tangible assets (which capture asset quality and collateral availability) accumulate more debt. The results also indicate that the effects of size and tangibility on corporate leverage are significantly greater in advanced economies than in developing countries. With a negative coefficient, effective interest rate is found to have a moderating influence on corporate leverage as expected, and this effect appears to be more pronounced in advanced economies. Finally, the results confirm that age matters for leverage, as more mature corporations borrow less than younger firms, and this effect is less pronounced among nonfinancial firms developing countries.

We also find a coherent picture with regards to the impact of macroeconomic factors on corporate indebtedness. First, the level of real income per capita has a statistically significant positive effect on leverage when the model is estimated for the sample as well as the subsample of advanced economies. Among emerging market economies, however, the coefficient on real

income per capita becomes negative, which implies that firms in more developed emerging markets tend to have a lower level of corporate leverage. While this could be partly because of data limitations (the number of observations in the subsample of emerging market economies is less than 10 percent of that in the subsample of advanced economies), it could also reflect that emerging-market firms tend to rely more on internal financing. Real GDP growth, on the other hand, has an economically and statistically significant negative effect on debt accumulation at the firm level across all countries, but still more pronounced in advanced economies than in developing countries. This implies that corporate debt overhang could become a strenuous burden on nonfinancial firms during severe economic downturns. Both trade openness and financial development are found to dampen corporate leverage, but the magnitude of these

Table 2. Determinants of Corporate Leverage—Baseline Estimations

Variables	(1) All	(2) All	(3) Advanced	(4) Advanced	(5) Developing	(6) Developing
	Dependent variable: Leverage					
Firm-level						
Profitability (lag)	-0.140***	-0.141***	-0.142***	-0.142***	-0.121***	-0.122***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.004]	[0.004]
Cash flow (lag)	-0.003***	-0.006***	-0.003***	-0.005***	-0.012***	-0.012***
	[0.000]	[0.000]	[0.001]	[0.001]	[0.002]	[0.002]
Sales growth (lag)	-0.000***	-0.001***	-0.001***	-0.001***	0.002***	0.002***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Tangibility (lag)	0.107***	0.105***	0.108***	0.107***	0.075***	0.074***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.004]	[0.004]
Total assets (lag)	0.044***	0.043***	0.045***	0.044***	0.028***	0.029***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Interest rate (lag)	-0.003***	-0.004***	-0.003***	-0.004***	-0.000	-0.001**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Age	-0.071***	-0.065***	-0.072***	-0.065***	-0.046***	-0.050***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.004]	[0.004]
Macroeconomic						
Real GDP per capita		0.013***		0.015***		-0.066***
		[0.002]		[0.003]		[0.011]
Real GDP growth		-0.340***		-0.372***		-0.170***
		[0.006]		[0.007]		[0.015]
Trade openness		-0.035***		-0.042***		-0.054***
		[0.002]		[0.002]		[0.006]
Financial development		-0.040***		-0.046***		0.047***
		[0.001]		[0.001]		[0.006]
Number of observations	10,425,382	10,426,274	9,769,226	9,769,639	656,156	656,635
Number of firms	1,867,105	1,867,227	1,728,796	1,728,859	138,309	138,368
Fixed effects	S*T*C	S*T+S*C	S*T*C	S*T+S*C	S*T*C	S*T+S*C
Adj R-squared	0.028	0.029	0.029	0.030	0.015	0.022

Note: Robust standard errors clustered at the firm level are reported in brackets. Firm fixed effects are included in all regressions. Singleton observations are excluded resulting in a slightly smaller number of observations in the specification with all three fixed effects interacted.
*** p<0.01, ** p<0.05, * p<0.1

effects vary across country groups. Trade openness appears to have a stronger negative impact in emerging market economies, while financial development influence corporate leverage in opposing ways in advanced and developing countries.

B. Determinants of Fixed Investment

Table 3 presents the baseline estimation results for corporate investment. Regarding our main variable of interest, we find a statistically significant and economically large negative relationship between corporate leverage and fixed investment spending. Firms with higher leverage tend to undertake significantly less fixed investment than others across all country groups and model specifications. In other words, greater levels of corporate indebtedness become increasingly detrimental to capital spending by non-financial firms. This effect is marginally higher in advanced economies than in developing countries, where nonfinancial firms have less debt on average. Profitability is found to have a significant positive effect, fueling firms' investment appetite across all country groups and model specifications. Cash flow, on the other hand, appears to matter for fixed investment spending in the full sample and advanced economies, but not for firms in developing countries. We observe the opposite behavior with regards to sales growth, the negative impact of which is significantly greater in emerging market economies. Both firm size and asset tangibility are found to have statistically significant dampening effects on fixed investment. Larger nonfinancial firms and firms and those with more tangible assets invest less, and the economic magnitude of these effects is comparable across country groups. With a negative coefficient, effective interest rate is associated with lower capital spending, but this effect does not appear to be statistically significant in emerging market economies, where firms tend to rely more on internal sources of financing. Finally, with regards to firm age, we find that older firms invest more than young corporations, especially in developing countries.

To enrich the analysis and tease out the impact of macrostructural differences across countries, we include a set of macroeconomic control variables. The quantitative results obtained with these model specifications are similar in terms of the direction, magnitude and statistical significance of estimated coefficients of firm characteristics. First, both the level and growth rate of real GDP per capita have a statistically significant boosting effect on nonfinancial firms' investment decisions across all countries, but the magnitude of these effects is marginally greater in advanced economies. Trade openness has a negative effect on firms' fixed investment spending across all country groups, but the size of this effect is almost twice as large in advanced economies than that in developing countries. Financial development, on the other hand, is found to have a positive significant effect on firm-level capital spending across all country groups, but its impact is significantly greater in emerging market economies where financial development is still in progress.

We conduct a number of robustness checks to verify our baseline findings and obtain a more nuanced picture of how corporate debt burden affects fixed investment at the firm level. First, we introduce additional firm-level variables (liquidity and capital intensity) and country-level control variables for institutional differences (corruption and the rule of law). These results, presented in Appendix Table A5, confirm the baseline findings. Second, the model is estimated separately for

1997-2007 to exclude the period after the global financial crisis and for 2008-2018 to focus on the post-crisis period. We split the sample and estimate the model separately for small and large firms as well as for low-indebted and highly indebted firms.[8] These results, presented in Appendix Table A6, remain broadly consistent with our baseline findings.

Table 3. Determinants of Fixed Investment—Baseline Estimations

Variables	(1) All	(2) All	(3) Advanced	(4) Advanced	(5) Developing	(6) Developing
			Dependent variable: Fixed investment			
Firm-level						
Leverage (lag)	-0.045***	-0.053***	-0.045***	-0.053***	-0.042***	-0.040***
	[0.002]	[0.003]	[0.002]	[0.003]	[0.011]	[0.012]
Profitability (lag)	0.038***	0.022***	0.038***	0.028***	0.041***	0.005
	[0.003]	[0.003]	[0.003]	[0.004]	[0.014]	[0.015]
Cash flow (lag)	0.000***	-0.000	0.000***	0.000	-0.000	-0.000*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Sales growth (lag)	-0.000***	-0.000***	-0.000***	-0.000***	0.000**	0.000**
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Tangibility (lag)	-0.362***	-0.378***	-0.360***	-0.378***	-0.405***	-0.396***
	[0.003]	[0.003]	[0.003]	[0.004]	[0.014]	[0.015]
Total assets (lag)	-0.078***	-0.044***	-0.078***	-0.048***	-0.103***	-0.049***
	[0.001]	[0.000]	[0.001]	[0.000]	[0.003]	[0.002]
Interest rate (lag)	-0.000***	-0.000***	-0.000***	-0.000***	-0.000*	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Age	-0.016***	-0.054***	-0.016***	-0.047***	-0.008	-0.025*
	[0.002]	[0.002]	[0.002]	[0.002]	[0.013]	[0.013]
Macroeconomic						
Real GDP per capita		-0.445***		-0.752***		0.096***
		[0.008]		[0.011]		[0.023]
Real GDP growth		-0.820***		-0.661***		-0.873***
		[0.036]		[0.038]		[0.103]
Trade openness		-0.321***		-0.460***		0.170***
		[0.007]		[0.008]		[0.015]
Financial development		-0.065***		-0.091***		-0.137***
		[0.003]		[0.003]		[0.016]
Number of observations	4,278,402	4,007,046	3,996,966	3,759,078	281,436	247,966
Number of firms	1,190,211	1,145,398	1,100,452	1,067,118	89,759	78,280
Fixed effects	S*T*C	S*T+S*C	S*T*C	S*T+S*C	S*T*C	S*T+S*C
Adj R-squared	0.045	0.033	0.046	0.034	0.044	0.032

Note: Robust standard errors clustered at the firm level are reported in brackets. Firm fixed effects are included in all regressions. Singleton observations are excluded resulting in a slightly smaller number of observations in the specification with all three fixed effects interacted.
*** p<0.01, ** p<0.05, * p<0.1

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[8] Small and large firms are defined as those whose total assets are below 25th percentile or above 75th percentile threshold, respectively. Low-indebted firms are those with leverage ratio below 25th percentile, while highly indebted firms are the ones with leverage above 75th percentile.

V. CONCLUSION

The global economy is in the midst of an unprecedented slump caused by the coronavirus pandemic. This is a systemic risk like no other at a time of record-breaking debt levels, especially among nonfinancial firms across the world. A protracted vicious cycle triggered by the COVID-19 pandemic—as experienced during the global financial crisis of 2008 and many times in various emerging market economies—could exacerbate corporate vulnerabilities, deepen macro-financial instability, and cause long-lasting damage to economic potential. While governments and central banks have responded by providing extensive fiscal stimulus, lowering interest rates and relaxing macroprudential regulations, uncertainty surrounding the pandemic has depressed risk appetite and pushed borrowing costs higher. Firms with high leverage are particularly vulnerable to declining revenues and increasing borrowing costs.

In this paper, we develop a two-pronged approach to investigate corporate vulnerabilities, using firm-level balance sheet data for a large dataset of more than 1.8 million nonfinancial firms from 52 countries over the period 1997–2018. First, we investigate the determinants of corporate leverage as measured by the total debt-to-assets ratio, taking into account country-specific characteristics; second, in view of the emerging economic and financial fault-lines across the world, we explore whether corporate debt overhang becomes a deterrent to fixed investment spending by nonfinancial firms. The empirical analysis, robust to a battery of sensitivity checks, confirm corporate leverage is highly vulnerable to disruptions in profitability and cash flow at the firm level and economic growth at the aggregate level. These findings provide strong evidence that corporate debt overhang could become a strenuous burden on nonfinancial firms, especially during severe economic downturns. Indeed, the second stage of our empirical investigation reveals that highly leveraged firms tend to have lower levels of fixed investment spending. These results are broadly in line with previous studies, but also brings new insights by analyzing a wider sample of firms across a broad set of countries over a long period.[9] In times of greater macro-financial uncertainty, corporate debt overhang is likely to depress nonfinancial capital investment for years to come, especially if the COVID-19 pandemic lingers and global downturn becomes protracted.

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[9] A plethora of recent studies reach similar results indicating that in advanced and emerging market economies (IMF, 2015; Antoun de Almeida and Tressel, 2017; IMF, 2019; Alter and Elekdag, 2020).

REFERENCES

Alter, A., and S. Elekdag, 2020, "Emerging Market Corporate Leverage and Global Financial Conditions," *Journal of Corporate Finance*, Vol. 62, pp. 1–51.

Antoun de Almeida, L. and T. Tressel, 2017, "Non-Financial Corporate Debt in Advanced Economies, 2010–17," IMF Working Paper No. 20/120 (Washington, DC: International Monetary Fund).

Arellano, M., and O. Bover, 1995, "Another Look at the Instrumental Variable Estimation of Error-Components Models," *Journal of Econometrics*, Vol. 68, pp. 29–51.

Blundell, R., and S. Bond, 1998, "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, Vol. 87, pp. 115–143.

Baker, M., and J. Wurgler, 2002, "Market Timing and Capital Structure," *Journal of Finance*, Vol. 57, pp. 1-32.

Bekaert, G., M. Hoerova, and M. L Duca, 2013, "Risk, Uncertainty and Monetary Policy," *Journal of Monetary Economics*, Vol. 60, pp. 771-788.

Borio, C., 1990, "Leverage and Financing of Nonfinancial Companies: An International Perspective," BIS Economic Papers No. 27 (Basel: Bank for International Settlements).

Borensztein, E., and L. Ye, 2018, "Corporate Debt Overhang and Investment: Firm-Level Investment," World Bank Policy Research Working Paper No. 8553 (Washington, DC: World Bank).

Booth, L., V. Aivazian, A. Demirgüç-Kunt, and A. Maksimovic, 2001, "Capital Structures in Developing Countries," *Journal of Finance*, Vol. 56, pp. 87-130.

Cecchetti, S., F. Mohanty, and F. Zampolli, 2011, "The Real Effects of Debt," BIS Working Paper, 352 (Basel: Bank for International Settlements).

Cerutti, E., S. Claessens, and D. Puy, 2015, "Push Factors and Capital Flows to Emerging Markets: Why Knowing Your Lender Matters More Than Fundamentals," IMF Working Paper No. 15/127 (Washington, DC: International Monetary Fund).

Cevik, S. and F. Miryugin, 2018, "Does Taxation Stifle Corporate Investment? Firm-Level Evidence from ASEAN Countries," *Australian Economic Review*, Vol. 51, pp. 351-367.

Cevik, S. and F. Miryugin, 2020, "Pandemics and Firms: Drawing Lessons from History," IMF Working Paper No. 20/[x] (Washington, DC: International Monetary Fund).

Chinn, M., and H. Ito, 2006, "What Matters for Financial Development? Capital Controls, Institutions, and Interactions," Journal of Development Economics, Vol. 81, pp. 163–192.

De Angelo, H., and R. Roll, 2015, "How Stable Are Corporate Capital Structures?" *Journal of Finance*, Vol. 70, pp. 373-418.

Feyen, E., S. Ghosh, K. Kibuuka, and S. Farazi, 2015, "Global Liquidity and External Bond Issuance in Emerging Markets and Developing Economies," World Bank Policy Research Working Paper No. 7363 (Washington, DC: World Bank).

Frank, M., and V. Goyal, 2009, "Capital Structure Decisions: Which Factors Are Reliably Important?" *Financial Management*, Vol. 38, pp. 1-37.

Gal, P., 2013, "Measuring Total Factor Productivity at the Firm Level Using OECD-ORBIS," OECD Economics Department Working Paper No. 1049 (Paris: Organization for Economic Co-operation and Development).

Giroud, X., and H. Mueller, 2017, "Firm Leverage, Consumer Demand, and Employment Losses during the Great Recession," *Quarterly Journal of Economics*, Vol. 132, pp. 271–316.

Graham, J., M. Leary, and M. Roberts, 2015, "A Century of Capital Structure: The Leveraging of Corporate America," *Journal of Financial Economics*, Vol. 118, pp. 532-551.

Gungoraydinoglu, A., and Ö. Öztekin, 2011, "Firm- and Country-Level Determinants of Corporate Leverage," *Journal of Corporate Finance*, Vol. 17, pp. 1457-1474.

Harris, M., and A. Raviv, 1991, "The Theory of Capital Structure," *Journal of Finance*, Vol. 46, pp. 297-355.

Im, K., M. Pesaran, and Y. Shin, 2003, "Testing for Unit Roots in Heterogeneous Panels," *Journal of Econometrics*, Vol. 115, pp. 53–74.

International Monetary Fund, 2015, "Corporate Leverage in Emerging Markets—A Concern?" Global Financial Stability Report, October (Washington, DC: International Monetary Fund).

International Monetary Fund, 2019, "Global Corporate Vulnerabilities: Riskier Business," Global Financial Stability Report, October (Washington, DC: International Monetary Fund).

Kalemli-Özcan, Ş., Sorensen, B., Villegas-Sanchez, C., Volosovych, V., and S. Yeşiltaş, 2015, "How to Construct Nationally Representative Firm-Level Data from the ORBIS Global Database," NBER Working Papers No. 21558 (Cambridge, MA: National Bureau of Economic Research).

Kalemli-Özcan, Ş., L. Laeven, and D. Moreno, 2019, "Debt Overhang, Rollover Risk, and Corporate Investment: Evidence from the European Crisis," ECB Working Paper No. 2241 (Frankfurt: European Central Bank).

Kayo, E., and H. Kimura, 2011, "Hierarchical Determinants of Capital Structure," *Journal of Banking and Finance*, Vol. 35, pp. 358-371.

Lang, L., E. Ofek, and R. Stulz, 1997, "Leverage, Investment, and Firm Growth," *Journal of Financial Economics*, Vol. 40, pp. 3-29.

Lemmon, M., M. Roberts, and J. Zender, 2008, "Back to the Beginning: Persistence and the Cross-Section of Corporate Capital Structure," *Journal of Finance*, Vol. 63, pp. 1575-1608.

Myers, S., 1984, "The Capital Structure Puzzle," *Journal of Finance*, Vol. 39, pp. 575–592.

Öztekin, Ö., 2015, "Capital Structure Decisions Around the World: Which Factors Are Reliably Important?" *Journal of Financial and Quantitative Analysis*, Vol. 50, pp. 301-323.

Rajan, R., and L. Zingales, 1995, "What Do We Know About Capital Structure? Some Evidence from International Data," *Journal of Finance*, Vol. 50, pp. 1421-1460.

Roodman, D., 2009, "How to Do xtabond2: An Introduction to Difference and System GMM in Stata," *Stata Journal*, Vol. 9, pp. 86–136.

Staiger, D. and J.H. Stock, 1997. "Instrumental variables regression with weak instruments". *Econometrica*, Vol. 65, pp. 557-586.

Titman, S., and R. Wessels, 1998, "The Determinants of Capital Structure Choice," *Journal of Finance*, Vol. 43, pp. 1-19.

APPENDICES

Appendix Table A1. Breakdown by Year

Year	Num. of obs.
1997	2,317
1998	2,965
1999	10,197
2000	14,024
2001	251,143
2002	291,733
2003	389,718
2004	477,346
2005	525,481
2006	614,713
2007	855,231
2008	953,859
2009	1,018,369
2010	1,087,112
2011	1,097,868
2012	1,131,531
2013	1,165,906
2014	1,159,494
2015	1,106,179
2016	1,144,517
2017	1,035,979
2018	197,963
Total	**14,533,645**

Appendix Table A2. Country Groups

Advanced	Developing
Austria	Algeria
Australia	Bosnia and Herzegovina
Belgium	Bulgaria
Canada	Brazil
Cyprus	China
Czechia	Colombia
Germany	Croatia
Denmark	Hungary
Finland	Kazakhstan
France	Malaysia
Greece	Mexico
Ireland	Montenegro
Iceland	Morocco
Italy	North Macedonia
Japan	Philippines
Korea	Poland
Lithuania	Russia
Luxembourg	Serbia
Latvia	Thailand
Malta	Turkey
The Netherlands	Ukraine
Norway	Vietnam
Portugal	
Singapore	
Slovakia	
Slovenia	
Spain	
Sweden	
United Kingdom	
United States	
13,511,498	**1,022,147**
	Total 14,533,645

Appendix Table A3. Summary Statistics

Variable	Unit	Min	p25	p50	p75	Max	Average	Std. dev.	Num. of obs.
Firm characteristics									
Leverage	Ratio	0.00	0.05	0.20	0.42	2.34	0.27	0.27	14,533,645
Fixed investment	Ratio	0.00	0.01	0.03	0.09	5.13	0.10	0.24	6,062,631
Total assets	Log	0.00	12.77	13.86	15.08	32.51	14.00	1.84	14,533,645
Profitability	Ratio	-3.21	-0.01	0.02	0.07	1.22	0.02	0.19	14,453,593
Asset tangibility	Ratio	0.00	0.05	0.20	0.47	0.99	0.29	0.28	14,477,526
Sales growth	Ratio	-1.00	-0.16	0.00	0.19	15.03	0.09	0.76	14,257,481
Cash flow	Ratio	-0.64	-0.02	0.00	0.03	2.27	0.01	0.13	14,289,598
Interest rate	Ratio	0.00	0.03	0.06	0.11	16.36	0.20	0.84	12,926,990
Age	Log	0.00	1.95	2.49	3.00	4.61	2.48	0.73	14,533,645
Liquidity	Ratio	0.00	0.89	1.29	2.13	216.3	2.84	8.91	14,412,022
Capital intensity	Ratio	-5.06	-0.43	-0.20	-0.09	0.00	-0.35	0.45	12,454,432
Macroeconomic controls									
GDP per capita	Log	6.80	8.98	9.97	10.70	11.63	9.75	1.08	951
GDP growth	Ratio	-0.15	0.01	0.03	0.05	0.25	0.03	0.03	951
Trade openness	Ratio	0.16	0.58	0.81	1.22	4.37	1.00	0.71	951
Private credit	Ratio	0.00	0.47	0.84	1.19	3.09	0.87	0.50	951
Corruption	Index	1.00	2.50	3.00	4.50	6.00	3.47	1.31	858
Rule of law	Index	1.00	4.00	5.00	6.00	6.00	4.61	1.23	858

Appendix Table A4. Fixed Investment Estimations by Sectors

Variables	(1) AGR	(2) MIN	(3) MFG	(4) UTI	(5) CON	(6) IT	(7) OTH	(8) TRD	(9) TRA	(10) EST	(11) ADM
					Dependent variable: Fixed investment						
Firm-level											
Leverage (lag)	-0.068***	-0.062**	-0.083***	-0.094***	0.006	-0.036**	-0.095***	-0.040***	-0.088***	-0.015*	-0.073***
	[0.012]	[0.027]	[0.005]	[0.021]	[0.007]	[0.015]	[0.013]	[0.005]	[0.011]	[0.008]	[0.009]
Profitability (lag)	0.003	-0.069	0.046***	0.029	0.038***	0.016	0.004	0.033***	0.021	0.021	-0.008
	[0.015]	[0.050]	[0.007]	[0.031]	[0.008]	[0.016]	[0.014]	[0.007]	[0.018]	[0.015]	[0.010]
Cash flow (lag)	-0.000**	-0.000	-0.000***	-0.000	0.000	-0.000	-0.000	0.000***	0.000	0.000***	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Sales growth (lag)	0.000**	0.000	-0.000***	-0.000	-0.000***	-0.000***	0.000	-0.000***	-0.000***	-0.000***	-0.000***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Tangibility (lag)	-0.411***	-0.253***	-0.468***	-0.335***	-0.319***	-0.424***	-0.411***	-0.409***	-0.312***	-0.284***	-0.354***
	[0.019]	[0.032]	[0.006]	[0.023]	[0.010]	[0.025]	[0.016]	[0.007]	[0.013]	[0.011]	[0.012]
Total assets (lag)	-0.031***	-0.014***	-0.020***	-0.019***	-0.054***	-0.077***	-0.046***	-0.058***	-0.028***	-0.066***	-0.069***
	[0.002]	[0.003]	[0.000]	[0.002]	[0.001]	[0.003]	[0.002]	[0.001]	[0.001]	[0.001]	[0.001]
Interest rate (lag)	-0.000**	0.000	-0.000***	0.000	-0.000***	-0.000	-0.001***	-0.001***	-0.000**	-0.000*	-0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Age	-0.050***	-0.063**	-0.077***	-0.097***	-0.039***	0.019	-0.088***	-0.037***	-0.037***	-0.000	-0.033***
	[0.011]	[0.025]	[0.004]	[0.013]	[0.007]	[0.019]	[0.011]	[0.005]	[0.009]	[0.009]	[0.010]
Macroeconomic											
Real GDP per capita	0.019	-0.074	-0.264***	-0.134***	-0.607***	-0.764***	-0.344***	-0.328***	-0.371***	-0.474***	-0.555***
	[0.022]	[0.064]	[0.010]	[0.040]	[0.029]	[0.073]	[0.046]	[0.017]	[0.036]	[0.037]	[0.043]
Real GDP growth	-0.381***	0.326	-0.753***	0.457***	-0.413***	-1.673***	-0.522***	-1.661***	-0.153	0.893***	-1.001***
	[0.141]	[0.243]	[0.054]	[0.168]	[0.104]	[0.274]	[0.163]	[0.075]	[0.138]	[0.146]	[0.147]
Trade openness	0.186***	-0.012	-0.161***	-0.122***	-0.582***	-0.714***	-0.325***	-0.290***	-0.209***	-0.501***	-0.450***
	[0.023]	[0.063]	[0.008]	[0.034]	[0.021]	[0.049]	[0.047]	[0.017]	[0.034]	[0.038]	[0.040]
Financial development	-0.012	-0.001	-0.081***	0.047***	-0.021**	-0.204***	-0.062***	-0.099***	-0.053***	0.159***	-0.098***
	[0.011]	[0.021]	[0.004]	[0.018]	[0.010]	[0.025]	[0.013]	[0.006]	[0.011]	[0.013]	[0.012]
Number of observations	110,734	18,165	975,832	60,514	539,967	106,286	176,411	1,147,000	193,075	320,315	353,277
Number of firms	31,557	4,591	254,733	15,818	161,324	33,251	54,353	329,775	52,459	96,667	109,748
Fixed effects	T+C	T+C	T+C	T+C	T+C	T+C	T+C	T+C	T+C	T+C	T+C
Adj R-squared	0.037	0.015	0.033	0.024	0.032	0.050	0.038	0.042	0.027	0.041	0.044

Note: Robust standard errors clustered at the firm level are reported in brackets. Firm fixed effects are included in all regressions. AGR – Agribusiness, MIN – Mining, MFG – Manufacturing, UTI – Utilities, CON – Construction, IT – Information technology, OTH – Other service activities, households, extra territorial bodies, TRD – Wholesale and retail trade, accommodation, TRA – Transport and storage, EST – Real estate, ADM – Professional and administrative activities.

*** p<0.01, ** p<0.05, * p<0.1

Appendix Table A5. Fixed Investment Estimations—Additional Controls

Variables	(1) All	(2) All	(3) Advanced	(4) Advanced	(5) Developing	(6) Developing
	Dependent variable: Fixed investment					
Firm-level						
Leverage (lag)	-0.043***	-0.054***	-0.043***	-0.053***	-0.043***	-0.068***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.013]	[0.017]
Profitability (lag)	0.054***	0.041***	0.052***	0.046***	0.081***	0.039**
	[0.004]	[0.004]	[0.004]	[0.004]	[0.015]	[0.017]
Cash flow (lag)	0.000***	0.000	0.000***	0.000	-0.000	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Sales growth (lag)	-0.000***	-0.000***	-0.000***	-0.000***	0.000**	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Tangibility (lag)	-0.374***	-0.389***	-0.372***	-0.391***	-0.412***	-0.361***
	[0.003]	[0.004]	[0.003]	[0.004]	[0.015]	[0.017]
Total assets (lag)	-0.076***	-0.043***	-0.076***	-0.047***	-0.098***	-0.056***
	[0.001]	[0.000]	[0.001]	[0.000]	[0.004]	[0.003]
Interest rate (lag)	-0.000***	-0.000***	-0.000***	-0.000***	-0.000*	-0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Age	-0.011***	-0.050***	-0.011***	-0.044***	-0.012	-0.053***
	[0.002]	[0.002]	[0.002]	[0.002]	[0.012]	[0.013]
Liquidity (lag)	-0.000**	-0.000	-0.000*	-0.000	-0.001**	-0.000*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Capital intensity (lag)	-0.084***	-0.106***	-0.080***	-0.101***	-0.275***	-0.219***
	[0.003]	[0.003]	[0.003]	[0.003]	[0.021]	[0.019]
Macroeconomic						
GDP per capita		-0.586***		-0.853***		0.169***
		[0.010]		[0.012]		[0.040]
GDP growth		-0.882***		-0.870***		-0.378**
		[0.045]		[0.046]		[0.159]
Trade openness		-0.337***		-0.434***		0.125***
		[0.008]		[0.009]		[0.023]
Financial development		-0.073***		-0.093***		-0.081***
		[0.003]		[0.003]		[0.028]
Rule of law		0.015***		0.036***		-0.015***
		[0.002]		[0.002]		[0.004]
Number of observations	3,721,468	3,440,685	3,510,217	3,293,636	211,251	147,043
Number of firms	1,029,214	977,855	961,454	931,525	67,760	46,329
Fixed effects	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C
Adj R-squared	0.047	0.035	0.047	0.036	0.050	0.046

Note: Robust standard errors clustered at the firm level are reported in brackets. Firm fixed effects are included in all regressions. Singleton observations are excluded resulting in a slightly smaller number of observations in the specification with all three fixed effects interacted.
*** p<0.01, ** p<0.05, * p<0.1

Appendix Table A6. Fixed Investment Estimations—Sub-samples

Variables	(1) Pre-GFC	(2) Post-GFC	(3) Small	(4) Large	(5) Low leverage	(6) High leverage
	Dependent variable: Fixed investment					
Firm-level						
Leverage (lag)	-0.083***	-0.017***	-0.125***	-0.012***	0.050***	-0.250***
	[0.004]	[0.006]	[0.005]	[0.004]	[0.010]	[0.006]
Profitability (lag)	0.009*	0.049***	-0.021***	0.152***	0.010	0.019**
	[0.005]	[0.009]	[0.007]	[0.004]	[0.009]	[0.009]
Cash flow (lag)	-0.000	-0.000***	-0.000**	-0.000***	-0.000***	0.000
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Sales growth (lag)	0.000*	-0.000***	0.000	-0.000***	-0.000***	0.000***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Tangibility (lag)	-0.474***	-0.581***	-0.519***	-0.472***	-0.404***	-0.756***
	[0.008]	[0.009]	[0.007]	[0.006]	[0.017]	[0.009]
Total assets (lag)	-0.082***	-0.198***	-0.029***	-0.405***	-0.072***	-0.057***
	[0.002]	[0.002]	[0.001]	[0.003]	[0.001]	[0.001]
Interest rate (lag)	-0.000	-0.001***	-0.000	-0.000	-0.000**	-0.001***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Age	-0.030***	-0.182***	-0.042***	0.211***	0.026***	-0.109***
	[0.005]	[0.007]	[0.006]	[0.005]	[0.010]	[0.006]
Macroeconomic						
Real GDP per capita	-0.043*	-0.347***	-0.262***	0.921***	-0.449***	-1.032***
	[0.022]	[0.020]	[0.021]	[0.016]	[0.034]	[0.023]
Real GDP growth	-0.325***	0.630***	-0.256***	-0.324***	-1.170***	0.167**
	[0.085]	[0.066]	[0.075]	[0.054]	[0.137]	[0.074]
Trade openness	-0.144***	-0.876***	-0.131***	-0.259***	-0.064*	-0.571***
	[0.034]	[0.013]	[0.017]	[0.010]	[0.036]	[0.016]
Financial development	-0.006	-0.170***	0.065***	0.037***	0.071***	-0.110***
	[0.006]	[0.008]	[0.005]	[0.006]	[0.012]	[0.008]
Number of observations	883,991	1,257,531	1,375,768	2,313,731	529,514	893,888
Number of firms	287,080	379,643	445,722	800,934	210,286	299,117
Fixed effects	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C	S*T+S*C
Adj R-squared	0.056	0.200	0.025	0.332	0.041	0.078

Note: Robust standard errors clustered at the firm level are reported in brackets. Firm fixed effects are included in all regressions. Singleton observations are excluded resulting in a slightly smaller number of observations in the specification with all three fixed effects interacted.

*** $p<0.01$, ** $p<0.05$, * $p<0.1$