Transformation in Production Technology and the Dynamics of Corporate Investment

FANGJIAN FU **SHENG HUANG** **RONG WANG***

ABSTRACT

Capital expenditures of U.S. public firms, relative to total assets, decrease by more than half from 1980 to 2016. The decline is pervasive across industries and firms of different characteristics, and cannot be explained by the usual determinants of investment and many other seemingly plausible reasons. The decline is consistent with the transformation in production technology – firms rely more on intangible capital and less on fixed assets in production. Industry-level analyses yield supporting evidence. We observe similar declining trend in capital expenditure in other developed countries but not in emerging markets.

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* Fu (fjfu@smu.edu.sg) and Wang (rongwang@smu.edu.sg) are with Singapore Management University, Lee Kong Chian School of Business. Sheng(shenghuang@ceibs.edu) is with China Europe International Business School. We thank Renee Adams, Heitor Almeida, Gennaro Bernile, Ekkehart Boehmer, Long Chen, Ralf Elsas, Yunjong Eo, Xavier Giroud, Radha Gopalan, Johan Hombert, Zsuzsa Huszar, Hyun Joong Im, Jonathan Jona, Brandon Julio, Ohad Kadan, Ambrus Kecskés, Mark Leary, Kai Li, Laura Liu, Roger Loh, Xiumin Martin, Roni Michaely, Vikram Nanda, Matthew Ringgenberg, Lucio Sarno, Yongseok Shin, Anjan Thakor, Fei Xie, Weike Xu, Jun Yu, and in particular, Sudipto Dasgupta, Phil Dybvig, and Jarrad Harford, as well as participants at Auckland Finance Meeting, China International Conference in Finance, Financial Management Association meetings, Greater China Area Finance Conference, Singapore Scholar Symposium, Fudan University, ESSEC Business School, Rutgers University, Massey University, Peking University, Renmin University, Shanghai University of Finance and Economics, Singapore Management University, Temple University, Tsinghua University, and Washington University in St. Louis for helpful discussions and comments. We also thank Meng Gao, Yuan Meng, Evelyn Toh, and Shuyu Xue for excellent research assistance. This paper was initially circulated with the title "Why Do U.S. Firms Invest Less over Time?"

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1. Introduction

Corporate capital investment is a key input of a firm's production process and a critical factor for the firm to survive and grow. Aggregated at the macro level it is also a fundamental driver of economic growth. Yet, U.S. firms have experienced a large and persistent decline in capital investment in the period 1980-2016. Figure 1 shows that the median firm's capital expenditure drops from 7.80% of its total assets in 1980 to 2.50% in 2016 – a cut by two thirds. The declines, measured by the mean and aggregate ratios of capital expenditure to total assets, are at a similar magnitude, and are all statistically significant in the Augmented Dickey-Fuller (ADF) time-series test. Why do U.S. firms invest so much less over time?

We start with examining several intuitive explanations that, however, fail to account for such a massive decline. First, we do not find that the decline is due to the shift in the industry composition of the economy. The U.S. economy has experienced a substantial structural change over our sample period. The services-producing sector has grown substantially relative to the goods-producing sector (Lee and Wolpin, 2006; Buera and Kaboski, 2012; among others).[1] One might conjecture that the decline could be due to the shift in the industry composition of the economy as services-producing industries are generally less capital-intensive. Our empirical findings, however, lend little support to this explanation. We find pervasive capital expenditure declines in almost all industries in the U.S. economy and the magnitudes of the declines are not necessarily larger for the shrinking industries than those of the expanding industries. Our further test confirms that what matters is the pervasive investment decline *within* each industry but not the time-varying industry composition of the economy.

Second, the decline is not driven by changes in firm characteristics. Neoclassical economic theories suggest that, in a frictionless capital market, a firm's optimal investment is solely determined by its investment opportunities. However, imperfect market conditions often lead to suboptimal investment.[2] A firm's actual investment is thus related to its

[1] For example, the industry of Business Services increases its asset weight in the economy from 2.00% in 1980 to 8.11% in 2016, while the asset weight of the steel industry drops from 5.29% to 0.85% during the same period.

[2] Examples of frictions often referred to in the literature include taxes, adjustment costs, information asymmetry, interest conflicts among stakeholders, etc.

investment opportunity set and other firm characteristics such as financial constraint.[3] While we confirm the literature on the cross-sectional relations between firm characteristics and capital expenditure, these characteristics do not account for the time-series decline in investment. No evidence suggests that the median U.S. firm has experienced diminishing investment opportunities, declining profitability, or tightening financial constraints over our sample period. Moreover, the declines in capital expenditure are not even less in magnitude for firms with rich investment opportunities or firms that are not financially constrained.

We further rule out several other potential explanations. (1) The decline in capital expenditure is not driven by newly listed firms. Newly listed firms often exhibit different features from their older peers such as the tendency to pay dividends (Fama and French, 2001) and to issue short-term debt (Custodio, Ferreira, and Laureano, 2013). However, the declining trend of capital expenditure remains even after we control for the fixed effects of public listing cohorts. (2) Corporate lifecycle does not explain the trend either. The corporate lifecycle hypothesis suggests that maturing firms often experience diminishing investment opportunities and consequently cut their investments. However, investment opportunities of U.S. firms (measured by the median market-to-book ratio of assets) generally improve over our sample period. Moreover, U.S. firms are, on average, not much getting older as many new firms get listed in the middle of our sample period. (3) The price of investment goods, especially equipment and software, which lowers as technology advances (Gordon, 1990; Greenwood, Hercowitz, and Krusell, 1997, Cummins and Violante, 2002) contributes to the decline of capital investment but leaves the predominant part of the decline unexplained. (4) We also rule out capital lease, depreciation, and change in accounting rules as potential drivers of the decline.

What is then underlying the massive decline in corporate capital expenditure? One fundamental change in the U.S. and other developed economies over the past few decades is the transformation in firm production technology. Traditionally, firms rely more on investment in fixed assets to grow. In recent decades, the advances in technology have

[3] One such example is the positive empirical relation between investment and cash flow. A high cash flow, however, could signal a relaxation of financial constraint, more profitable investment opportunities, or an aggravation of agency problems; all of them predict more investment even though the underlying mechanisms differ drastically.

significantly enhanced the productivity of both manufacturing and services firms (Brynjolfsson and Hitt, 1995,1996, and 2000), and reduced firms' reliance on fixed assets (acquired through capital expenditure) and increased the importance of intangible capital in firm production (e.g., Lev and Radhakrishnan, 2005; Corrado and Hulten, 2010; Lustig, Syverson, and Van Nieuwerburgh, 2011; Eisfeldt and Papanikolaou, 2013 and 2014; Falato, Kadyrzhanova, and Sim, 2014). Intangible capital, as an increasingly important input in production, facilitates a more efficient combination of physical capital and human capital into production and creates value.[4] Our finding of the pervasive decline in capital expenditure across industries is consistent with such an economy-wide transformation. Our further analysis and evidence, both domestically and globally, suggest that transformation in production technology is likely the driving force of the decline in corporate capital expenditure.

First, using industry-level data of gross output and various inputs in firm production from the Bureau of Economic Analysis's (BEA) annual industry accounts, we find that industries in the U.S. that employ more intangible inputs (purchased services, employee compensation) and less physical inputs (energy, materials) tend to cut capital expenditure more. In addition, using U.S. census microdata on employees from IPUMS (collected in American Community Surveys (ACS)), we show that industries increasingly hiring more highly-educated employees also cut capital expenditure in greater magnitude.

Second, we find that the U.S. pattern of corporate investment is not unique but rather representative in economies that have experienced similar transformation in production technology. Economic globalization in the past decades facilitates and accelerates the transformation in firm production technology. Globalization enables the developed economies to outsource their capital-expenditure-intensive manufacturing activities to developing economies, and focus on the more profitable parts of the production, such as product development, design, and marketing which usually require less physical capital investment and more intangible investment and high-skill human capital (Apple Inc. is such an example). Thus, under the production technology transformation explanation, we expect to

[4] Examples of intangible capital investment include expenditures on R&D, information technology, product development and design, marketing, business processing systems, human capital and organizational development, etc.

observe a decline in corporate capital expenditure in other developed economies too, but not in developing economies. Using international data, we indeed find a similar decline in capital expenditure for firms in G7 and OECD countries, but not in the fast-growing emerging economies such as the BRICS (Brazil, Russia, India, China, and South Africa).

In addition, the transformation in production technology and the associated change in corporate investment behavior are consistent with several noteworthy changes occurred to U.S. firms. First, the shift in the relative importance of physical and intangible capital in firm production implies a corresponding change in firms' asset structure. As firms invest less in fixed assets and more in intangible capital, we confirm in our empirical analysis that the fraction of physical assets in total book assets decreases and the fraction of intangible assets increases over time. Second, investment theory suggests that a firm's optimal investment responds to its investment opportunities. A large empirical literature has examined how firms' investment in fixed assets is related to investment opportunities. We argue that, with the transformation in production technology, adapting firms that employ more intangible capital in production will become less responsive in physical investment to new investment opportunities, *ceteris paribus*. We confirm in the data a significant and persistent time-series reduction in the sensitivity of capital expenditure to investment opportunities.[5]

The time-series change in the composition of corporate investment affects how we view and measure corporate investment. First, the increasing importance of intangible capital in firm production suggests that we should take investment in intangible capital into account when we examine a firm's investment activity. Second, we need a better understanding and calibration of the relation between capital expenditure and intangible investment. On the one hand, capital expenditure and intangible investment can be substitutes in view of capital allocation under resource constraint. In addition, more investment in intangible capital can potentially improve the efficiency of fixed assets and reduce a firm's reliance on fixed assets. But on the other hand, capital expenditure and intangible investment play different roles in firm production, and thus can also be complements. The enhanced efficiency due to increased investment in intangibles could well prompt the firm to expand its production for a higher

[5] Asker, Farre-Mensa, and Ljungqvist (2015) also document a declining sensitivity of investment to investment opportunities for U.S. public firms (Figure 7 in p365), though it's not the focus of their study.

market share, leading to more capital expenditure. To illustrate, we examine the empirical relation between capital expenditure and R&D (an important type of intangible investment), both at the industry and the firm levels. We find that industries that invest more in R&D tend to have a smaller decline in capital expenditure and within firms, R&D expenses are also positively related to capital expenditure. The complicated interaction between intangible and physical investments cautions us researchers whether it's appropriate to take the simple sum of different types of investment as the measure of total corporate investment and draw inferences from it. But even if we follow recent studies to include R&D and a proportion of SG&A expenses as the measure of intangible investment and simply add it to capital expenditure in measuring total investment, we still find a significant decline in this measure of total investment, as shown in Figure 8.

Our study contributes to the literature in several ways. We examine corporate investment of U.S. firms in a long horizon and identify a robust, pervasive, and somewhat puzzling decline of corporate capital expenditure.[6] Existing theories of corporate investment, due to their micro perspective, fall short in explaining the decline trend. We show that it is consistent with U.S. firms' transformation in production technology – an increasing reliance on intangible capital in production. Firms adapt their investment policy to the new production technology and economic environment. It has profound implications on our understanding of corporate investment theories and calls for a dynamic view on corporate investment behavior.

Our study adds to the burgeoning literature on the role of intangible capital in firm production.[7] Our findings, based on firm level data, are consistent with the macro level evidence in Corrado, Hulten, and Sichel (2009) and Corrado and Hulten (2010) about the shift of investment from physical capital towards intangible capital in the U.S. economy, which, according to them, boosts aggregate economic growth. Our micro-level evidence confirms the transformation in production technology that firms in various industries rely more on intangible capital and less on capital expenditure in generating profits and growth.

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[6] Kahle and Stulz (2017) document a similar decline in capital expenditure for U.S. public firms, but they do not conduct a comprehensive study for the potential explanations. Two other contemporaneous studies, Alexander and Eberly (2018) and Gutierrez and Philippon (2017), also examine the decline in corporate investment.

[7] See Lev (2001), Atkeson and Kehoe (2005), Lev and Radhakrishnan (2005), Faria (2008), Corrado, Hulten, and Sichel (2009), Corrado and Hulten (2010), Carlin, Chowdhry, and Garmaise (2012), Lustig, Syverson, and Van Nieuwerburgh (2011), Eisfeldt and Papanikolaou (2013, 2014), among others.

Our study also sheds light on some recent findings in corporate finance. For instance, Chen and Chen (2012) and Asker, Farre-Mensa, and Ljungqvist (2015) find that the investment-cash flow sensitivity and the investment-investment opportunity sensitivity, respectively, steadily decline over time. We confirm these findings and suggest that the increasing importance of intangible capital in firm production helps to explain these findings. Likewise, Wang and Zhang (2015) suggest that, due to the increased employment of intangibles in production and more intensive competition, current cash flow contains less information about future cash flow, which results in the decline of the investment-cash flow sensitivity. Bates, Kahle, and Stulz (2009) document an increasing trend of cash holding by U.S. firms since 1980 and suggest that firms are increasingly precautionary to save cash. Our study suggests that both the decline in capital expenditure and the increase in cash holding are consistent with the transformation in production technology and the increasing intangibility of assets (and uncertainty) in the U.S. firms. In a recent study, Falato, Kadyrzhanove, and Sim (2014) propose that the increase in asset intangibility reduces debt capacity and leads firms to hold more cash to preserve financial flexibility.

The corporate investment dynamics also have important implications for investment-based asset pricing theories. Empirical models of the investment-based asset pricing theories have achieved some success in explaining certain cross-sectional return anomalies (e.g., Lyandres, Sun, and Zhang, 2008; Li, Livdan, and Zhang, 2009; and Hou, Xue, and Zhang, 2015). Corporate investment in these models is often measured by capital expenditure or growth in book assets, which however fails to capture investment in intangible capital. Given the value implications of intangible capital (e.g., Lev and Sougiannis, 1996; Eisfeldt and Papanikolaou, 2013), it is possible that, after appropriately accounting for intangible investment, these models are able to do an even better job in explaining stock return variations.

Two recent studies examine aggregate corporate investment and, especially, its relation with stock market returns of the near periods. Kothari, Lewellen, and Warner (2015) find that U.S. firms' quarterly growth in fixed assets investment is positively related to the lagged corporate profit growth and stock market returns but negatively related to the subsequent profits and stock returns. Interestingly, they find investment growth is largely unrelated to recent changes in market volatility, interest rates, and the default spread on corporate bonds. Arif and Lee (2014) find that aggregate capital expenditure increases during periods of positive investor sentiment and is then followed by lower stock market returns. They suggest that aggregate corporate capital expenditure could capture, and therefore is a valid measure for, market-wide investor sentiment. Our study differs by examining the time-series trend in aggregate capital expenditure in a long horizon and, from the corporate perspective, exploring the potential explanations for the trend. We do not examine its relation to stock market returns.

2. The sample and the time-series evidence of corporate capital expenditure

Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (Standard Industry Classification (SIC) codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded to mitigate the regulation effects on corporate policies. We require firm total assets (AT) and capital expenditure (CAPX) data items available in the Compustat fundamental annual file. Our base sample consists of 14,281 unique firms with 125,370 firm-year observations.

Our primary variable is a firm's annual capital expenditure divided by its total assets as of the previous fiscal year end (CAPX/AT). According to the Compustat data definition, capital expenditure represents cash outflow or funds used for additions to the company property, plant, and equipment, excluding amounts arising from acquisitions but including expenditure on capital leases.[8] Table 1 presents the mean, median, and aggregate ratios of capital expenditure to total assets from 1980 to 2016, which are also plotted in Figure 1. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms in a given year divided by the sum of these firms' total assets as of the previous fiscal year end. Not surprisingly it is more affected by larger firms. All three ratios in Figure 1 decline substantially even though there are short-term fluctuations with macroeconomic cycles. If we compare the three ratios in 2016 to those in 1980, the drops are about two thirds. Like many

[8] Capital expenditure includes expenditures for capital leases. While operating lease is not accounted in capital expenditure (it is often accounted as operating expenses and affects the income statement), it does not affect the denominator, total assets, either. For multi-national firms, capital expenditure in Compustat is a consolidated figure. It includes capital expenditure made by U.S. firms' overseas subsidiaries, for example, P&G's investment in their China and Indian divisions. The same is for total assets.

other corporate financial ratios, the capital expenditure ratio is positively skewed – the mean ratio tends to be higher than the median. The aggregate ratio resembles closely to the average ratio, suggesting the decline is not driven by small or large firms only. The number of firms in our sample starts with 3,110 in 1980, peaks at 4,942 in 1997, and declines to 2,673 in 2016, exhibiting an inverse U-shape.

Next we employ an augmented Dickey-Fuller (ADF) test to examine the time trend formally. We run the following time-series regression:

$$\Delta\left(\frac{CAPX}{AT}\right)_{t+1} = \alpha + \beta * Trend_t + \gamma * \left(\frac{CAPX}{AT}\right)_t + \theta * \Delta\left(\frac{CAPX}{AT}\right)_t + \varepsilon. \quad (1)$$

The dependent variable is the change in the capital expenditure ratios between the two subsequent years, t+1 and t, where t = 1980, 1981, …, 2016. The explanatory variables on the right-hand side include a time trend variable "*Trend*" defined as (t -1979)/1000, the level of capital expenditure in fiscal year t, and the lagged change in capital expenditure.[9] The coefficient on *Trend*, β, captures the time trend of CAPX/AT. The coefficient, γ, tests the existence of a unit root in the capital expenditure ratio. Our specification of using the change in capital expenditure has accounted for the potential existence of a unit root. Nevertheless, whether or not there is a unit root does not invalid our test of the trend.

Regression results are reported in Panel A of Table 2, in three columns respectively corresponding to the mean, median, and aggregate ratios of capital expenditure. The coefficient estimates of *Trend* in all three regressions are negative and statistically significant at the 5% level, confirming a decreasing time trend. The economic magnitude is substantial and fairly consistent across different measures. The estimate of γ suggests that we are not able to reject the existence of a unit root in the mean and median ratios of CAPX/AT. Note that the significance test for γ is based on the critical values of the augmented Dickey-Fuller unit root test, in particular, -3.22 for significance at the 10% level, -3.57 for 5%, and -4.31 for 1%.

Capital expenditure is supposed to increase a firm's fixed assets, frequently called property, plant, and equipment (PP&E) in accounting terms. If firms continue to cut capital expenditure, we expect to observe a drop in fixed assets as a proportion of total assets. To

[9] The choice of one lagged change in capital expenditure is determined by Bayesian information criterion (BIC); our empirical results are, however, robust to controls of up to four lags of capital expenditure changes.

verify, we decompose total assets (AT) into three components: current assets (ACT), net property, plant, and equipment (PPENT), and intangible assets (INTAN). Figure 2 plots the mean, median, and aggregate ratios of each component relative to total assets. We find a persistent decline in PPENT/AT for all three metrics, as a result of the secular reduction in capital expenditure. On the other hand, we find a substantial increase in intangible assets. The ratio of current assets to total assets also decreases over time, suggesting that the decline in capital expenditure is not caused by accumulation of more current assets.[10]

Alternative Definition of Corporate Investment. Our study follows the conventional definition of corporate investment, that is, capital expenditure. In a broader concept, corporate investment could also include expenses on research and development (R&D) and acquisitions. It is natural to ask whether firms reduce capital expenditure to increase expenses on R&D or acquisitions, that is, is there a substitution between capital expenditure and R&D and acquisition expenses? In accounting, capital expenditure increases a firm's fixed assets (i.e., property, plant, and equipment), while R&D is usually expensed even though it increases a firm's expected intangible assets. This suggests they are very different in nature. An acquisition could increase both tangible and intangible assets, though the impact also depends on the target firm nature and the accounting method (pooling vs. purchasing).

We include both R&D and acquisition expenses into the calculation of the investment ratio. Figure 3 plots the time series of the three aggregate ratios (CAPX/AT, (CAPX+R&D)/AT, (CAPX+R&D+AQC)/AT). We still find the declining pattern with statistical significance. Though R&D gains more importance over time, it is still relatively small in magnitude compared to capital expenditure. Acquisitions often come in waves, with the alternation of hot and cold markets (Harford, 2005). Including it, not surprisingly, renders the time trend more volatile. Moreover, in later analysis in Section 4.1.5 with results tabulated in Table 4, we show that CAPX/AT drops as significantly in firms that have never reported any expenses on R&D or acquisitions during the whole sample period as it does in

[10] One might find the decline in current assets surprising because Bates, Kahle, and Stulz (2009) have shown that over this time period U.S. firms increase holdings of cash, which is an important component of current assets. Our further examination reveals that, while increasing cash holdings, U.S. firms in the meantime reduce non-cash current assets, such as inventory, and the reduction in non-cash current assets outweighs in magnitude the increase in cash holdings.

other firms. The decline in capital expenditure does not seem to be replaced by increases in R&D and acquisition expenses, at least in these firms.

The Impact of Macroeconomic Factors. Macroeconomic factors could affect aggregate corporate investment. Bernanke and Gertler (1989) suggest that a positive shock to the economy improves firms' profits and retained earnings; this in turn leads to increased investment and output. This acceleration mechanism amplifies the upturn. Corporate investment is also affected by the tightness of the credit market. Bernanke and Gertler (1995) provide a survey for the literature. In general, firms invest more when the economy is growing fast and when it is easy for them to borrow capital in the market. To investigate if the observed investment decline is explained by macroeconomic factors, we include the changes in GDP growth rates, credit spreads, short-term rates, and term spreads in Equation (1). The results are reported in Panel B of Table 2. For brevity, we only report the results based on the aggregate ratio of CAPX/AT as the dependent variable. The results based on the mean and median ratios are qualitatively similar. We find that firms invest more when GDP grows fast, when term spread is less, and when short-term rate increases. The relation between change in investment and credit spread is not significant. The coefficient estimate for the trend variable nevertheless remains negative and statistically significant in all specifications, and there is little reduction in the magnitude.

The Price of Investment Goods. The price of investment goods generally declines over time, as a result of technological progress (see, e.g., Gordon, 1990; Greenwood, Hercowitz, and Krusell, 1997, Cummins and Violante, 2002). One such example is computing power. If so, our finding of the decline in capital expenditure could be a result of cheaper investment goods. To control for the impact of the decreasing price of investment goods, we adjust the numerator of the CAPX/AT ratio by a price index of investment goods, which was originally constructed in Gordon (1990).[11] We report the adjusted CAPX/AT ratios in the last three columns of Table 1 and also plot the time-series aggregate ratio in Panel A of Figure 4 (the upper panel) in comparison with the raw aggregate ratio. Reduction of investment goods prices indeed accounts for part of the decline in capital expenditure. For example, the drop,

[11] The price index of investment goods is originally constructed in Gordon (1990) for the period of 1947-1983, extended to 2000 in Cummins and Violante (2002), and extended further in DiCecio (2009). We appreciate Riccardo DiCecio of Federal Research Bank for kindly sharing with us his data, which were extended to 2015.

measured by the median CAPX/AT, is about 65% before the price adjustment while it decreases to 56% after the adjustment. The effects of adjustment are similar for the other two ratios of CAPX/AT. We therefore conclude that the decreasing price of investment goods has a significant impact but it still leaves a larger portion of investment decline unexplained. In fact, price reduction suggests that a firm can save capital expenditure on per unit of equipment, but does not explain why the firm does not invest on more units of equipment.

The Impact of Depreciation. Technology improvement may enable corporate fixed assets more durable than before – firms replace their fixed assets less frequently. Is the investment decline due to a slower depreciation of fixed assets over time? We check the time trend of the ratio of depreciation expenses to fixed assets (DP/PPEGT). DP is the depreciation and amortization expense for fixed assets on balance sheet. PPEGT is the gross value of fixed assets. In contrast to the conjecture, DP/PPEGT has increased slightly during our sampler period, suggesting a faster replacement of fixed assets.[12] This evidence thus does not support the speed of depreciation as a potential justification for the decline in capital expenditure.

The Impact of Private Firms. Our sample consists of U.S. public firms traded at the three major stock exchanges. Is it possible that the decreased public firm investment is replaced by an increase in private firm investments? We do not have firm-level data for all private firms and thus are not able to conduct analysis as we do for public firms. We, however, gauge the potential impact of private firms using aggregate data from U.S. Federal Reserve.[13] The Federal Reserve's Financial Accounts provide aggregate flow of funds and balance sheet data, where we obtain the private non-residential fixed investment (PNFI) data and the book value of total assets for non-financial corporate business, which include both private and public U.S. corporations. We compute the ratio of PNFI to total assets and plot the time-series in Panel B of Figure 4 (the lower panel).[14] We find that this aggregate ratio also experiences a significant and similar decline in our sample period. Specifically, the ratio drops from 7.53% in 1980 to 5.53% in 2016. The evidence suggests that the investment

[12] The time-series plot of DP/PPEGT is available upon request.
[13] Data source: http://www.federalreserve.gov/releases/z1/Current/data.htm
[14] The non-financial component of assets is evaluated at historical costs, similar to the book value of assets in the Compustat data.

decline of public firms is not offset by the change in capital investment (if any) by private firms.

3. Industry composition and the decline in capital expenditure

The results above show that U.S. firms, on average and in aggregate, invest less over time. During our sample period the services-producing sector of the U.S. has grown rapidly relative to the goods-producing sector, resulting in a substantial shift in the structure of the U.S. economy.[15] According to the Bureau of Economic Analysis (BEA) data, the value-added of the service (goods) producing sector as a percentage of GDP has grown (declined) steadily from 56% (30.2%) in 1980 to 68.8% (18.3%) in 2016.[16] Accordingly, the fraction of workers employed in the service (goods) sector has grown (declined) from 53.6% (26.9%) in 1980 to 70.5% (15.4%) in 2016.[17,18] Thus, the aggregate decline in capital expenditure could result from the variation in industry compositions – the contraction of traditionally CAPX-heavy industries and the expansion of CAPX-light industries in the economy.

To investigate if the investment decline is concentrated in certain industries, we conduct two tests. First, we run the regression in Equation (1) at the industry level, where the sample is classified into 44 Fama and French (1997) industries.[19] Table IA.1 in the internet appendix reports the estimates of β and the associated t-statistics for each industry. Based on the industry median CAPX/AT, out of the 44 industries in total, 42 industries (95.5%) show a declining trend in capital expenditure and in 31 of them (70.5%), the declining trend is statistically significant. Only two industries (petroleum and natural gas; fabricated products) observe a positive β for the time trend variable but neither of them is statistically significant. The examination on the industry mean ratio shows that the decline occurs in all 44 industries

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[15] According to Bureau of Economic Analysis, the goods-producing sector consists of industries such as agriculture, forestry, fishing, hunting, mining, construction, and manufacturing.

[16] U.S. Bureau of Economic Analysis, "Table 4a. Value Added by Industry Group as a Percentage of GDP", https://www.bea.gov/system/files/2018-07/gdpind118_3.pdf (accessed on October 12, 2018).

[17] Anecdotal observations also suggest a substantial variation in industry composition in the last few decades. For instances, computer software, as an industry that barely exists in the early 1970s, has evolved into a crucial component of the economy in the new century. The business services industry is another example of fast growing industries. On the other hand, manufacturing industries such as construction materials and steel works have contracted significantly in the U.S. economy during our sample period.

[18] U.S. Bureau of Economic Analysis, "Table 5.5D. Full-Time Equivalent Employees by Industry", https://apps.bea.gov/iTable/iTable.cfm?reqid=19&step=3&isuri=1&categories=survey&nipa_table_list=197 (accessed on October 12, 2018).

[19] The Fama-French scheme classifies firms into 49 industries, but five industries, namely, utilities, banking, insurance, real estate, and trading, are excluded from our sample.

and is statistically significant in 37 of them (84.1%). The results based on the industry aggregate CAPX/AT are very similar – declines are observed in 42 industries and 31 of them are statistically significant. Fabricated Products is the only industry that shows a marginally positive increase in aggregate investment. The evidence suggests that the investment decline is pervasive; in the meantime, there are substantial variations in the magnitude of declines across industries.

Next we evaluate how much of the decline in CAPX/AT is due to the variation of industry composition in the U.S. economy. Our test is simple yet intuitive. We take the first year (1980) and the last year (2016) of the sample as the two points of comparison. To estimate the change in the industry composition of the economy during our sample period, for each industry we first compute the percentage of its total assets in the whole sample (%Assets). This measure is used to capture the economic importance of the industry in the economy.[20] The estimates in the first year and the last year of our sample, as well as their differences, are reported in Table 3. Indeed, we find substantial variations of industry composition during the period. For example, in 1980 the computer software industry has only 14 firms whose total assets amount to 0.02% of the whole sample. In 2016 the number of firms increases to 138 and their total assets weight increases to 4.37%. Other fast expanding industries include business services, communication, and pharmaceutical products. In contrast, the number of firms in the steel industry decreases from 81 in 1980 to 29 in 2016 and the assets weight decreases from 5.29% to 0.85%. The construction material industry reduces its firm number from 183 to 38 and the assets weight drops from 3.92% to 0.64%. Petroleum and natural gas is another industry that experiences a sharp decline in the economy. Its firm number decreases from 177 to 129 and the assets weight decreases from 13.67% to 9.44% over the sample period.

Next, we compare the aggregate ratio of CAPX/AT in 1980 with that in 2016 by industries. The results are also reported in Table 3. We note a few interesting observations. First, consistent with the results in Table IA.1, the capital expenditure ratio drops in all industries except the industry of fabricated products, regardless of whether the industry is

[20] Our results in the following analysis are robust to the use of the percentage of sales as a measure of industry weight.

expanding or shrinking. Our further examination suggests that the change in asset weights and the change in CAPX/AT ratios between the two time points are negatively correlated with a correlation coefficient of -0.22 and a significance level of 5%. In other words, fast-growing industries tend to have larger cuts in capital investment than shrinking industries. This is inconsistent with the prior that the largest drops in capital expenditure should occur in those traditional, shrinking industries. Our second finding sheds light on the puzzle. Some fast-growing and service-oriented industries actually have quite high capital expenditure ratios in 1980 while the traditional goods-producing industries do not necessarily have high ratios of capital expenditure. For example, the capital expenditure to asset ratio of computer software, one of the fastest growing industries, is 21.02% in 1980, which is the highest among all industries in that year. As a comparison, the capital expenditure ratio in 1980 is 7.82% for the agriculture industry, 5.76% for the apparel industry, and 2.74% for the fabricated products industry. It is not always true that traditional goods-producing industries rely more on fixed assets than those new, fast-growing industries and therefore, the variation in industry composition fails to explain the aggregate decline in capital expenditure of our sample.

Lastly, to quantify how much of the aggregate investment decline is due to the change in industry composition (the weight effect) and how much is due to the change in capital expenditure within industries (the level effect), we compute two hypothetical aggregate investment ratios. For the first one, we use the industry CAPX/AT in 1980 and their assets weights in 2016 to compute the aggregate investment ratio. In doing so, we in fact assume that CAPX/AT of each industry does not change from 1980 to 2016 (mute the level effect), so that the difference between the hypothetical aggregate investment ratio and the actual aggregate ratio in 1980 is solely due to the change in industry composition – the weight effect. For the second one, we use the industry CAPX/AT in 2016 and their asset weights in 1980, which effectively assumes no change in industry compositions from 1980 to 2016 (mute the weight effect); therefore, any deviation between the hypothetical aggregate investment ratio and the actual ratio in 1980 is solely due to the within-industry change in CAPX/AT – the level effect. The first hypothetical ratio calculated is 11.51%,[21] which is very close to the actual aggregate ratio of 11.26% in 1980. This suggests that the decline in capital expenditure is not at all attributed to the change in industry composition.[22] The second hypothetical ratio is 4.41%, which is very close to the actual aggregate ratio of 4.00% in 2016. This implies that the pervasive within-industry investment declines can explain the majority of the decline in the aggregate investment ratio, even assuming no variation in industry asset weights since 1980. The evidence casts serious doubt on the time-variation of industry composition as a potential explanation for the investment decline.

4. Firm characteristics and the decline in corporate investment

Theories have proposed various firm characteristics to explain corporate investment. In this section, we investigate if the time-series decline in investment is explained by the time-series variation in firm characteristics, or concentrated in (driven by) firms of certain characteristics. We conduct first univariate analysis and then multiple regressions.

4.1. Univariate Analysis

4.1.1. Investment opportunity

In theory, a firm's investment is fundamentally driven by its investment opportunities. Thus, we examine whether the time-series decline in investment is driven by the change in investment opportunities of U.S. firms over time. If so, we expect to observe: (1) The investment opportunities of U.S. firms shrink over time; and (2) the decline is more evident in firms with fewer investment opportunities.

We use Tobin's *q* and sales growth to measure investment opportunities. As shown in Figure IA.1 in the internet appendix, we find that investment opportunities, on average, increase during our sample period; the median market-to-book asset ratio increases from 1.0 in 1980 to 1.6 in 2016. In a time-series regression, we confirm the increasing trend over our

[21] Note that if we multiply the assets weight with the aggregate CAPX/AT ratio of each industry in 1980 (or 2016) and sum up the products across all industries, we get the aggregate CAPX/AT of 11.26% for 1980 (or 4.00% for 2016), as presented in Table 1. Similarly, to calculate the first (or second) hypothetical ratio, we multiply the assets weight of each industry in 2016 (or 1980) with the aggregate CAPX/AT ratio of each industry in 1980 (or 2016) and sum up the products across all industries.

[22] If it were due to the change in industry composition – the contraction of traditionally CAPX-heavy industries and the expansion of CAPX-light industries in the economy, we should have observed the first hypothetical investment ratio (which assumes varying industry weights but constant investment level) to be much lower than the actual ratio in 1980 (11.26%) and preferably close to the actual ratio in 2016 (4.00%).

sample period. This evidence challenges shrinking investment opportunity as a potential reason for the decline in investment.

To examine the investment trend across firms of different investment opportunities, we cut the sample each year into two subsamples of firms with high and low investment opportunities, based on the median market-to-book asset ratio (or sales growth) in the previous year. Table 4 presents the median CAPX/AT ratios respectively for the high- and low-investment-opportunity subsamples during each of the five-year subperiods (the last subperiod 2010-2016 has seven years) and the full period. Consistent with theory, firms with more investment opportunities invest more in the cross-section. The CAPX/AT ratio is higher for the subsample of firms with higher market-to-book asset ratios or sales growth. Comparing over time across the subperiods, we find that CAPX/AT decreases in both subsamples of high- and low-investment-opportunities. The last column of this table reports the coefficient estimates of the trend variable and the associated statistical significance from the regressions specified in Equation (1). It is somewhat surprising that even firms with more investment opportunities do not keep up their capital expenditures (we revisit this issue in Section 5). The results also cast doubt on time variation in investment opportunities as an explanation for the time-series decline in investment.

4.1.2. Financial constraint

In a perfect capital market, a firm's investment is independent of its financing problems. Investment opportunity is a sufficient statistic for its optimal investment. However, in an imperfect capital market with market frictions, external financing such as equity and debt become more expensive than internal funds. Thus a firm's investment may be constrained by its internal funds and its access to the external capital market. Studies such as Fazzari, Hubbard, and Petersen (1988) find that investment is positively related to the firm's cash flow, even after controlling for Tobin's q.[23,24] We investigate if firms with greater financial constraint are responsible for the declining trend of capital investment.

[23] See also Hoshi, Kashyap, and Scharfstein (1991) and Whited (1992), among others. Hubbard (1998) provides a comprehensive review of the literature.

[24] The interpretation of this empirical finding is controversial. Fazzari, Hubbard, and Petersen (1988) interpret it as evidence of financing constraint affecting corporate investment and suggest the investment-cash flow sensitivity as a measure of financial constraints. However, Gomes (2001), Alti (2003), Cooper and Ejarque (2003), and Abel and Eberly (2011) theoretically demonstrate the positive relation between investment and cash flow in the absence of

We use a firm's cash flow ratio to measure the availability of internal funds. Following Almeida, Campello, and Weisbach (2004), we also use firm size, payout ratio, and bond ratings to measure financial constraint. A firm is classified as more financially constrained if the above variables (except bond ratings) are below the sample median in a given year. [25]

Our univariate analysis results reported in Table 4 are consistent with the cross-sectional effect of financial constraint on investment. The literature suggests that large firms, firms producing high cash flows, firms with high cash payout, and firms with (investment-grade) credit ratings are less subject to the adverse selection problem and thus are less financially constrained. We show in Table 4 that these firms indeed invest more than their counterparts in the cross-section. Over time, however, both groups of firms reduce capital expenditure. The time-series declines are most significant for large firms, firms producing high cash flows, firms with relatively high payout and (investment-grade) credit ratings. The results that less financially constrained firms have larger declines in capital expenditure are inconsistent with financial constraint explaining the investment declines.

In addition, we examine the time series trend of the cash flow ratio. Figure IA.1 in the internet appendix plots the median cash flow ratio in each year during our sample period. The ratio is generally stable. In a time-series regression, we confirm that there is neither a significant upward nor a downward trend in the median cash flow ratio over our sample period. To sum up, the evidence does not support financial constraint as a potential explanation for the time-series decline in investment.

4.1.3. Agency problems

Capital market imperfections lead to a potential relation between corporate investment and firm leverage. Myers (1977) describes a debt overhang problem, in which a firm may underinvest relative to the optimal amount when its debt level is too high. The debt overhang

financing constraints. Hennessy, Levy, Whited (2007) show that the convex costs of external equity may lead to the positive relation between investment and cash flow. Kaplan and Zingales (1997) empirically challenge the positive relation between investment and cash flow as evidence of financial constraint. Erickson and Whited (2000) suggest that errors in measuring marginal q result in the positive relation between investment and cash flow.

[25] Small firms, firms with low cash flow, and firms with low payout are assumed to have a higher degree of financial constraint. For bond ratings, we use dummy variables to capture firms with or without a bond rating, and firms with investment-grade or speculative ratings. Unrated firms and firms with speculative ratings are expected to be more financially constrained. Firm size could also be related to investment if there are economies of scale to invest. In addition, since we deflate investment by firm size (total assets), the negative relation between the investment ratio and firm size could also be mechanical.

problem described in Myers (1977) predicts a negative relation between investment and leverage – high leverage and financial distress result in underinvestment. The agency conflicts between managers and shareholders, on the other hand, predict overinvestment. Jensen (1986, 1993), for example, argues that managers' empire-building preferences will cause them to invest excessively; abundant internal fund exacerbates the overinvestment problem. This leads to the prediction that investment is increasing in internal funds. To control the problem, Jensen (1986) suggests debt can be a disciplinary mechanism, which implies that (over)investment decreases with leverage. Other managerial characteristics might also affect firm investment, such as short-termism, herding tendency, inertia, and overconfidence.[26]

The results in Table 4 from splitting the sample based on the median leverage ratio of each year are inconsistent with the agency problem hypothesis for the investment decline. First, there is little evidence for a negative cross-sectional relation between leverage and investment in the overall sample. A closer look suggests that, in the early periods, low leverage is associated with larger corporate investment. This cross-sectional pattern, however, seems to reverse in the later periods. Secondly, both groups of firms show a negative and significant trend in the median capital expenditure, but firms with low leverage show a larger time-series decline. The results from splitting the sample based on cash holdings are inconsistent with the overinvestment explanation either. We do not find a significant difference in capital expenditure across firms with different levels of cash holdings. If any, the decline is more pronounced in the low-cash holding subsample, which presumably has less concern of free cash flows.

In short, the evidence of larger investment declines in firms with less extent of agency problems suggests that agency costs do not seem to explain the decline in capital expenditure. Moreover, if low internal funds and high leverage also characterize financial constraint, the

[26] See Stein (2003) for a survey of the literature. These managerial characteristics predict either over- or under-investment. For example, inertia predicts managers prefer "a quiet life", so they do not invest when good investment opportunities arise and are reluctant to liquidate poor projects in which investments have already been made. The empirical support for these hypotheses is mostly in the cross-section. For the interest of our paper, we assume that these managerial characteristics are more or less stable over time and unlikely to cause the secular decline in firm investment.

larger investment declines for firms that are less or not financially constrained again challenge financial constraint as a possible explanation.

4.1.4. Capital productivity

We examine the time trend in capital expenditure across firms of different capital productivities. One may argue that firms need to invest less because per unit of capital becomes more productive over time. In a conventional production function such as the Cobb-Douglas function, economic output is a function of labor and capital inputs. The parameters reflect technology and the relative importance of the inputs. If a firm's production is labor intensive, it relies less on capital investment. For a given amount of output, its average capital productivity is usually higher. On the other hand, a firm with capital intensive production generally has lower average capital productivity. Average capital productivity thus signals the relative importance of capital investment in a firm's production.

We measure a firm's capital productivity by the ratio of sales to PP&E (i.e., property, plant, and equipment) and split the sample in each year based on the median capital productivity. Our univariate analysis confirms that, in the cross-section, firms with lower capital productivity (i.e., capital-intensive) tend to invest more than firms with higher capital productivity. In the time-series, firms with both high and low capital productivities experience significant declines in capital expenditure. If any, the magnitude of decline is larger for capital-intensive firms. Therefore, an increase in capital productivity is not underlying the decline in capital expenditure.

4.1.5. R&D and acquisitions expenses

In a broader concept, corporate investment could also include expenses on research and development (R&D) and acquisitions. Do firms reduce capital expenditure to increase expenses on R&D or acquisitions, that is, whether there is a substitution between capital expenditure and R&D and acquisition expenses? In Figure 3, we show including R&D and acquisitions expenses does not eliminate the trend of investment decline.

We further investigate this conjecture as follows. We divide the sample into two groups depending on whether a firm has reported R&D expenses during the whole sample period 1980-2016. So the non-R&D group consists of firms that have never reported any R&D expenses over the nearly four decades. Similarly, we divide firms into the acquirer and non-acquirer groups depending on whether or not they have reported any acquisition expenses. During our sample period, 48.92% of the firms have not reported any R&D expenses and 40.35% of the firms have not reported any acquisition expenses. Table 4 presents the time series results of the median CAPX/AT ratio. The time-series decline in investment is statistically significant for firms in both the R&D and non-R&D groups, and in both the acquirer and non-acquirer groups, and the magnitude of decline is very similar in both pairs.

In summary, the univariate analysis confirms the cross-sectional relations between capital expenditure and firm characteristics, as proposed in extant theories of investment. However, none of these factors explains the time-series decline in investment. The decline occurs in firms with both high and low investment opportunities, in both large and small firms, in firms that seem to be financially constrained or not seemingly constrained, in firms with both high and low cash holdings or leverage, and in firms expensing or not on R&D and acquisitions.

4.2. Multiple regressions

Next we investigate the relation between capital expenditure and various firm characteristics in multiple regressions. This method has been used in Bates, Kahle, and Stulz (2009) in explaining the time-series changes in corporate cash holding and in Custodio, Ferreira, and Laureano (2013) in explaining the time-series changes in corporate debt maturity. Unlike the augmented Dickey-Fuller tests which focus on the investment ratios at the aggregate level, our micro-level multivariate tests are able to control for the firm-level time-series and cross-sectional variations in the determinants of investment. This allows us to evaluate if the declining trend detected in Table 2 can be explained by variations in firm characteristics.

Table 5 reports the regression results. In column (1) of Table 5, we employ a linear time trend as the only explanatory variable. The coefficient estimate indicates a significant decrease in CAPX/AT with the magnitude of almost 0.20% per year. This is consistent with our finding in Panel A of Table 2. Column (2) of Table 5 combines the time trend variable with the three controls in the baseline regression model. The results confirm again the findings of earlier studies that capital expenditure is positively related to investment opportunity and cash flow, and negatively related to firm size. The trend coefficient remains at 0.20% and significant at the 1% level. In Column (3) of Table 5, we control for additional firm characteristics including market leverage ratio, capital productivity, R&D expenses, payout ratio, and sales growth. Most of these variables have significant impact on investment, as indicated by their statistically significant coefficient estimates; however, the trend coefficient estimates remain negative and statistically significant with these additional controls. Column (4) controls for industry fixed effects and column (5) controls for firm fixed effects. The results on the trend coefficient are similar to that in column (3). In summary, after controlling for (the time-series and cross-sectional variations in) firm size, investment opportunities, cash flow, and other firm characteristics, we still observe a significant trend of decline in capital investment. The characteristics that explain cross-sectional variations in corporate investment account for little of the time-series decline.

4.3. Impact of corporate lifecycle

Studies have shown that corporate lifecycle is an important factor behind many firm decisions such as financing and dividend policies. It is also known that a firm's investment opportunities are abundant in its early life but may diminish over time as it matures. For example, Pastor and Veronesi (2003) show a convex decline in a typical firm's market-to-book ratio along its age. It is possible that our findings reflect a maturing process of typical U.S. firms and their diminishing investment opportunities. However, we have shown earlier that U.S. firms' investment opportunities, proxied by market-to-book asset ratios and sales growth, are not declining, and changes in investment opportunities are unlikely to be explaining the decline in capital investment.

Nevertheless, we investigate the impact of firm age on capital expenditure. We measure firm age since it is listed and included in the CRSP database.[27] The results are plotted in Figure 5. The upper panel plots the average listing (at CRSP) age of our sample firms. It is about 15 to 25 over time. There is a slight increase in average firm age in recent years, perhaps as a result of fewer firms going public since 2000. The lower panel shows the median CAPX/AT for firms of different ages. We find that firms indeed invest more during the first three to five years and then cut down investment quickly. However, the decline in capital

[27] We also measure firm age by the number of years since founded. The data on a firm's founding year is obtained from Jay Ritter's website. The sample size is much smaller with this alternative firm age measure. Nevertheless, our results still hold with this alternative measure of firm age.

expenditure does not persist beyond five years; instead firms maintain a flat pace of investment afterwards. The evidence suggests that corporate lifecycle is unlikely to be an explanation for the time-series decline in capital expenditure, since most of the firms are much older than five.

To account for the potential impact of corporate life cycle on investment (at least in the first few years), we control for firm age in firm-level regressions. Column (1) of Table 6 reports the results. It is true that elder firms tend to invest less than younger firms on average; we, however, still find a significantly negative time trend even after controlling for firm age.

4.4. New listing effect

IPOs in the U.S. come in waves. Firms cluster to go public in certain “hot” years while IPO activities subside in other “cold” years. Firms listed in different decades often exhibit different features in many aspects. Pastor and Veronesi (2005) suggest that technology innovations could be the underlying driver behind these waves, which explains that firms going public at different decades have their specific characteristics. For example, many IPO firms in 1990s are internet firms. The specific characteristics may affect optimal corporate policies. Fama and French (2001), for example, find that newly listed firms tend not to pay dividends. Custodio, Ferreira, and Laureano (2013) suggest that newly listed firms in recent decades use more short-term debt and are responsible for the general decrease in U.S. firms’ debt maturity. We thus investigate if the decline in capital expenditure is similarly driven by newly listed firms.

To capture the potentially different levels of investment for firms of different listing cohorts, we include in the investment regressions six dummy variables that indicate the decade when a firm was listed. For example, the 1950-1959 dummy is set to be one if a firm was listed in 1950s and zero otherwise. The benchmark cohort is firms listed prior to 1950. If our finding of the investment decline is driven by newly listed firms, we expect the listing dummies to be negative (and more negative for the later cohorts) and the coefficient of the time trend variable insignificant after controlling for the listing cohort dummies. The regression results are reported in Column (2) of Table 6. The coefficient estimate of the time trend variable remains significantly negative, and the magnitude is even larger than that of the estimate from the regression without controlling for listing cohorts (Column 1 of Table 5).

The listing dummies have positive, significant, and monotonically increasing coefficient estimates for firms listed in 1970s and thereafter, and insignificant coefficients for firms listed in 1950s and 1960s. This suggests that average investment does vary across listing cohorts and firms listed after 1970 actually have higher average capital expenditure than firms listed earlier. In Columns (3) and (4) where we control for the CRSP firm age, most of the listing dummies become insignificant. This is due to the high correlation between the CRSP age and listing dummies. The coefficients of the time trend remain negative and statistically significant in all models.

5. Transformation in production technology and corporate investment

What underlies the massive and widespread decline in corporate capital expenditure? Over the past few decades, one fundamental change in the U.S. economy is the transformation in firm production technology. Traditionally, firms, especially manufacturing firms, rely on investment in fixed assets to grow. In recent years, the development of the Internet and information and communications technology (ICT) has significantly enhanced the productivity of both manufacturing and services firms (Brynjolfsson and Hitt, 1995; 1996; 2000), [28] and transformed the production process of almost every firm and industry. It is often referred to as the Third Industrial Revolution. We posit that the transformation in firm production technology, triggered by technology advances, demands firms to invest less in fixed assets and more in intangible capital.

Rich anecdotal evidence seems to be consistent with the argument. For example, both technology companies like Apple and apparel companies like Nike nowadays focus primarily on product development, design, and marketing, and outsource product manufacturing, which requires significant amount of physical capital, to their overseas business partners. Department stores such as Macy’s and Nordstrom traditionally need to invest much capital to own or lease store spaces in expensive commercial districts. Current online stores enable these firms to consolidate and build their warehouses in cheaper areas without sacrificing access to potential customers. Studios in entertainment industries nowadays use computers to achieve much of the graphical effects which they used to spend a great amount of capital

[28] Hitt (1999) find that the increasing use of IT reduces the costs of coordinating economic activities within and between firms (internal and external coordination).

expenditure to achieve. IBM, known in the past as a computer and hardware manufacturer, is now a computer technology and IT consulting corporation. The decrease in IBM's capital expenditure is phenomenal – from 27% of its total assets in 1980 to 3.2% in 2016.

The transformation in production technology reduces firms' reliance on fixed assets, and at the same time hinges more on intangible capital in firm production. Intangible capital creates value by facilitating a more efficient combination of physical capital and labor into production. According to Lev and Radhakrishnan (2005), "[Intangible capital] is the major factor of production that is unique to the firm and thus capable of yielding abnormal – above cost of capital – returns, thereby generating enterprise growth." Examples of intangible capital investment include expenditures on R&D, information and communications technology, product development and design, marketing, business processing systems, human capital and organizational development, etc. While the effects on firm productivity and efficiency are apparent, investment in intangible capital and its importance are not recognized as much as investment in tangible assets. Both firm-level and national income accounting practices have historically treated expenditures on intangible inputs, such as R&D, software purchases, and costs of acquiring expertise, as intermediate expenses. Hence, intangible capital investment does not result in an immediate increase in firm assets or country GDP. Robert Solow remarked in 1987 that "you see the computer revolution everywhere except in the productivity data" (*New York Times*, July 12, 1987).

Only recently have studies started to advocate the great importance of intangible capital in firm production and national economic growth. For example, Corrado, Hulten, and Sichel (2009) argue that U.S. economic growth is significantly understated due to the omitted accounting of intangible capital. They show that investment in intangibles plays a significant role in the growth of labor productivity (i.e., output per worker per hour) and total output.[29] Further, Corrado and Hulten (2010) argue for the positive linkage between intangible investment and the increase in productivity at the firm level. Specifically, a company's increased expenditures on intangible capital lead to an upward shift in the production curve and ultimately drive economic growth. Lev and Radhakrishnan (2005) measure firm

[29] Lewis, Siemen, Balay, and Sakate (1992) find that the most important factor explaining productivity differences across countries is the organization of labor – how labor is used in combination with other inputs in producing output, which also highlights the importance of intangible capital in productivity.

organization capital – a major component of intangible capital, and show that it explains a significant portion of the cross-sectional variation in firm value, beyond the traditional determinants. Lustig, Syverson, and Van Nieuwerburgh (2011) suggest that firm productivity growth evolves from vintage-specific growth, which only affects newly-born firms of a specific period, to more general productivity growth, which makes all firms more productive with the widespread employment of intangible capital in production. Even for firms that traditionally rely heavily on physical capital, intangible capital investment also improves the efficiency of their production. As a result, intangible capital could affect firm production in almost every industry in the U.S. economy.

Indeed, the pervasive decline in capital expenditure across the vast majority of industries that we documented earlier is consistent with such an economy-wide transformation in production technology. In the following, we provide more direct evidence on how the transformation in production technology relates to the change in corporate capital expenditure, both in the U.S. and internationally.

5.1. Evidence on the impact of transformation in production technology on corporate investment

5.1.1 Cross-industry evidence

Under the transformation in production technology explanation, we expect to observe an increase in the employment of intangible inputs and a relative decrease in the employment of physical inputs in firm production. Moreover, we expect the time-series change in the use of physical (intangible) inputs to be positively (negatively) related to the change in capital expenditure. In addition, new production technology increases a firm's reliance on higher quality human capital. Therefore, we also expect the change in firms' employment of high-skill human capital (versus relatively low-skill human capital) to be negatively related to the change in capital expenditure. Our empirical analysis proceeds in two parts as follows.

The change in the use of physical and intangible inputs We start with the analysis of the use of physical/intangible inputs at the industry level. The Bureau of Economic Analysis' (BEA) annual industry accounts collect industry-level data of gross output and various inputs.[30] Gross output is the goods and services produced by an industry in a given year. It

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[30] Source: http://www.bea.gov/industry/io_annual.htm

reflects the value of various inputs (which are grouped into three categories – energy, materials, and purchased services[31]) that each industry consumes in producing its gross output and the additional value created by the industry's labor and capital in the production (value added). The value added is used to account gross domestic product (GDP). It includes the industry's return to labor (compensation of employees), return to government (taxes), and return to capital. Note that the data on gross output, value added by labor and capital, and the inputs in aggregate date back to 1987, while a breakdown of the aggregate inputs into the three categories (energy, materials, and purchased services) becomes available only since 1997.

Although from the perspective of GDP accounting, compensation of employees is accounted as value added (and thus contributes to the GDP), from the perspective of firm production it is more appropriate to be regarded as an input, similar to the other three categories – energy, materials, and purchased services. Among them, energy and materials are physical inputs while labor and purchased services can be regarded as intangible inputs. We posit that a firm's investment in intangible capital is more likely to be achieved through its increased employment of labor and purchased services, for example, hiring talented employees, training employees to be more productive, purchasing consulting services and IT services to improve business process systems, etc.. To measure the importance of each type of input in industry production, we compute its percentage of value relative to the total of the four inputs in each year. Using value percentages purges away the impact of input price changes due to inflation.

The breakdown data show a steady decrease (increase) in the use of materials (purchased services) in the U.S. firm production. In aggregate, the percentage of materials in the total inputs drops from 33% in 1997 to 26% in 2016. In comparison, the percentage of purchased services increases from 26% in 1997 to 31% in 2016. The percentages of energy and employee compensation largely remain stable at the aggregate level during the period of 1997-2016 (about 2~3% for energy and 38~40% for employee compensation). There are still significant variations across industries. For example, the percentage of employee compensation for the electronic equipment industry increases from 30% in 1997 to 56% in

[31] Examples of purchased services include professional and business services and information technology services.

2016. It increases from 44% to 56% for the software industry during the same period. Casual observations suggest that industries that cut capital expenditure the most tend to have reduced the use of materials/energy and increased the use of purchased services/labor as inputs in production. For example, the electronic equipment industry, which incurs one of the largest decreases in capital expenditure, features a significant increase in employee compensation and a modest reduction in the employment of materials. On the other hand, the petroleum and natural gas industry that experiences little decrease in capital expenditure witnesses a significant increase in the use of materials and a decrease in both purchased services and employee compensations.

To further examine how the transformation in production technology affects capital investment, we run industry-level regressions of the change in capital expenditure on the changes in materials, purchased services, energy, and labor, each as a share of the total inputs. Industries are reclassified into the Fama-French 49 industries, to be consistent with our earlier examinations on the declining trend. The dependent variable is the year-to-year change in the aggregate ratio of capital expenditure to total assets. Panel A of Table 7 reports the regression results. Columns (1) to (4) pertain to each of the four inputs, respectively.[32] We confirm that the decreases in materials and energy and the increases in purchased services and labor are all significantly related to the decline in capital expenditure in the cross-section of industries. The economic magnitude of the impact is substantial. For example, the coefficient estimate in Column (2) suggests that when purchased services increase by one standard deviation (1.24%), capital investment decreases by 0.12% (-0.094*1.24%), a magnitude comparable to the average annual decrease in capital investment by 0.17% at the industry level during 1997-2016. In column (5), we include the changes in purchased services, energy, and labor in the regression. We omit the change in materials because the four ratios add up to be one by construction. The estimated results are similar to those in columns (1) to (4). Though not tabulated for the reason of brevity, the results are robust to the control of annual changes in industry characteristics such as size, market-to-book, and profitability.

[32] Note that the sample period for energy, materials, and purchased services breakdown data is 1997-2016, and the sample period for labor compensation is 1987-2016.

The change in the employment of high-skill vs. low-skill human capital Recent research shows that technology advance and transformation in production technology increases firms' reliance on more high quality human capital and have an impact on the landscape of the labor market. Autor and Dorn (2013) argue that recent computerization and automation have substituted for low-skill, routine-tasks, mid-income occupations and spurred the growth of high-educated workers to perform the abstract, creative, problem-solving, and coordination tasks, leading to the polarization of the US labor market. Ma, Ouimet, and Simintzi (2017) propose that M&As facilitate adoption of more advanced firm production technology and find that an M&A event is associated with a 4.4% reduction in the share of establishment routine job and a 1.3% increase in the share of high skill workers at the target. Based on these finding, we use the employment of high-skill workers to capture the production technology transformation, and investigate how the declines in capital expenditure are related to changes in firms' employment of high-skill human capital.

Following prior studies, we use three measures of human capital – the percentage of employees with high school degree, the percentage of employees with college degree, and the percentage of employees with more than five years' college education. The employee information is obtained from IPUMS. IPUMS collects U.S. census microdata, which is surveyed every ten years prior to 2000, and from 2000 on, is collected annually in American Community Surveys (ACS).[33] The census data are originally at individual level. We aggregate them into industry-level data by matching the industry variable in the database to the Fama-French industry classifications (via NAICS and SIC codes). We run the industrial-level regressions of the changes in the capital expenditure ratios on the three measures of human capital variations. Panel B of Table 7 reports the regression results. We confirm that, industries that over time employ more highly-educated employees experience a larger cut in capital expenditure. The results are robust to three different education levels, with or without control variables in the regressions. These findings provide direct evidence on the impact of transformation in production technology on the investment in physical assets – industries employ more high-skilled employees over time tend to cut capital expenditure more.

[33] More information of the database can be found via https://usa.ipums.org/usa/

Overall, the evidence in this section lends strong support to the decreasing importance of physical assets and the increasing importance of intangibles such as human capital and services in production. Industries that tilt towards more intangible inputs in production tend to cut more investment in fixed assets, adapting to the transformation in production technology.

5.1.2 International evidence

In the last few decades during our sample period, globalization is one of the most distinguishing characteristics of the world economy.[34] It is often argued that globalization triggers the move of many labor-intensive productions, which often require heavy physical capital investment (e.g., factories, machines, and equipment), from developed economies such as the U.S. to emerging economies such as China and India with relatively cheaper labor costs. Apple Inc. and Nike Inc. are such examples that although their products are mainly designed in the U.S., the manufacturing of them is done overseas. Economic globalization could thus facilitate and accelerate the transformation in production technology and lead to the reduction in capital expenditure. Therefore, if the production technology transformation explanation holds, the U.S. pattern of corporate investment should not be unique. We expect to observe a similar pattern of investment decline for firms in countries with a similar level of economic development as in the U.S., but different patterns for firms in countries to which the U.S. and other developed economies shift their CAPX-heavy manufacturing activities.

Our international data, obtained from DataStream for the period 1980-2016, include 38 foreign countries that have data of no fewer than 50 publicly listed firms for at least five consecutive years in each country. Utilities, banks, and financial service firms are again excluded. Appendix B describes the international sample, including the country name, number of firm-year observations, sample period, starting year of sample coverage, and the median and aggregate ratios of capital expenditure to total assets (CAPX/AT). The last column indicates whether the country belongs to G7, OECD, or BRICS (the acronym for the five fast-growing emerging economies – Brazil, Russia, India, China, and South Africa).

[34] Several notable events affect the U.S. economy profoundly during our sample period 1980-2016, such as North American Free Trade Agreement (NAFTA), General Agreement on Tariffs and Trade (GATT) Tokyo Round and Uruguay Round, World Trade Organization (WTO) and China's entry into the WTO.

Clearly, our data tend to include more developed economies due to the poor coverage of emerging economies in DataStream especially in the early decades.

We plot the median, mean, and aggregate ratios of CAPX/AT for the international sample in Figure 6. The declines in both the mean and the median ratios are similar to the U.S. evidence. The median ratio drops from 6% in 1980 to less than 3% in 2013. The aggregate ratio, however, shows the least decline, suggesting the existence of some outlier countries with greater influence (such as China in the later period). Next we investigate the patterns by dividing the countries into two groups, based on if they belong to G7/ OECD / BRICS countries or not. Figure 7 presents the patterns. In general, the decline in capital expenditure is most evident in G7 and OECD countries, similar to the U.S. evidence. The decline is less obvious in other countries and not found in BRICS. Note the BRICS sample starts only in 1991 as there are fewer than 100 data points in the prior years.

Lastly, for each of the 31 countries that have data for at least 12 years, we run the time-series regressions of the augmented Dickey-Fuller test as we did for the U.S. firms in Equation (1). The regression coefficient for the time trend variable and its associated t-statistics are reported in Table 8. We find that most countries, especially the developed economies, observe declines in capital investment. In comparison, most developing economies, including BRICS and some other relatively smaller ones, do not experience significant investment declines. The results are consistent with our observations in Figure 6. We conclude that the decline in capital expenditure is not unique to the U.S. firms. It also occurs in other relatively more developed economies such as G7 and OECD countries, but less so for developing economies. The evidence is consistent with the transformation in production technology in relatively developed economies where firm production involves more intangible capital and thus requires less capital expenditure on fixed assets.

5.2. Implications of the transformation in production technology

The transformation in production technology has important implications for the time-series dynamics of corporate investment behavior. Neoclassical theory of investment suggests that a firm's optimal investment responds to its investment opportunities. A large volume of empirical literature has examined the relation between corporate investment, Tobin's q, and cash flows, in the vast majority of which physical investment has been the focus. The decreasing importance of physical capital in production implies a weaker relation between these factors over time. We thus examine if the sensitivities of capital expenditure to investment opportunity and cash flows decrease over time.

We augment the baseline OLS regression of the investment model (specification (2) in Table 5) by interacting the three main explanatory variables – log(AT), V/AT, and CF/AT – with the time trend variable. The coefficients on the interaction terms with V/AT and CF/AT are of key interest, which capture how the sensitivities of capital expenditure to Tobin's q and cash flows vary over time. Peters and Taylor (2017) propose a new Tobin's q proxy (labeled as "Total q") for a firm's investment opportunities that accounts for its intangible capital.[35] We thus conduct an additional regression with V/AT being replaced by Total q to see how the sensitivity of capital expenditure to Total q changes over time. To address the problem of potential estimation bias due to measurement error in Tobin's q in OLS regressions, we also estimate the investment model using Erickson, Jiang, and Whited's (2014) cumulant estimators as an additional check. They show that their cumulant estimators in the finite sample perform better than the moment estimators in Erickson and Whited's (2002).

The results are presented in Table 9. The first two columns report the results based on the OLS estimates and the last two columns based on the Erickson, Jiang, and Whited (2014) estimates. Both estimates yield similar findings on the sensitivities of capital expenditure to the market-to-book asset ratio, Total q and the cash flow ratio. While the coefficients on the V/AT (or Total q) and CF/AT are significantly positive, the coefficients on their interactions with the time trend variable are negative and statistically significant. That is, the sensitivities decline over the sample period. Firms do not increase capital expenditure in response to new investment opportunities or to profitability as much as they did in the earlier periods. Asker, Farre-Mensa, and Ljungqvist (2015) compare the investment behavior between public and private firms and show similar declining investment sensitivity for U.S. public firms even starting from 1970's. Our analysis suggests that the decline is associated with the transformation in production technology.[36] In robustness tests, we also confirm the reduced

[35] More details on their construction of a firm's intangible capital follow in the next subsection. We are grateful to Luke Taylor for sharing with us their data on intangible capital investment and Total q.

[36] Likewise, Chen and Chen (2012) also find that the investment-cash flow sensitivity steadily declines over time and finally disappears in their sample period of 1967-2009.

sensitivities for the subsample of manufacturing firms. This suggests that the decreasing importance of physical investment as an input in firm production also applies to those firms that traditionally rely more heavily on physical assets.

5.3. Further Discussions

5.3.1. The relation between capital expenditure and intangible investment

The transformation in firm production technology is manifested by the decreasing importance of the conventional type of corporate investment – capital expenditure – and the increasing importance of intangible investment in firm production over time. An important implication is that when we examine a firm's investment behavior, we should take both capital expenditure and intangible investment into account. An interesting question arises: What is the relation between capital expenditure and intangible investment; are they substitutes or complements? This question is important regarding how to view and deal with corporate investment in general. For instance, can we simply add up capital expenditure and intangible investment in measuring corporate investment, as in some recent studies?

The answer to this question is not trivial. From the perspective of resource allocation, if a firm is financially constrained, capital expenditure and intangible investment would compete for the firm's limited financial resources. Moreover, intangible investment potentially improves the efficiency of fixed assets and therefore, for any fixed amount of output, the enhanced efficiency reduces the demand for fixed assets and hence the firm's capital expenditure. As a result, capital expenditure and intangible investment can be substitutes.

However, capital expenditure and intangible investment can also be complements, due to their very different nature. In the above example, the enhanced efficiency due to increased investment in intangibles could prompt the firm to expand its production for a higher market share (depending on its product market structure), leading to an increase in capital expenditure. Consistent with this reasoning, we find that, at the industry level, the change in CAPX/AT is *positively* correlated with the change in R&D/AT (R&D is widely regarded as an important type of investment in intangibles). The correlation coefficient is as high as 0.27 (p-value < 0.0001). Industries that increase R&D expenses more also increase capital expenditure more (or reduce it less) in the same year, and industries that cut capital expenditure the most are also industries that invest the least in R&D. This finding is consistent with Hombert and Matray (2018) who show that, in response to the intensified competition due to imports from China, US manufacturing firms that have invested more in R&D are more resilient in sales growth and maintaining profitability and moreover, they are less likely to cut capital expenditure and employment.

Our empirical results at the firm level, as shown in Table 5, illustrate the contrasting relations between R&D and capital expenditure under different analytical frameworks. The coefficient estimate for R&D is negative in Column (3) but positive in Column (5), depending on whether or not controlling for firm fixed effects in the regressions. Without controlling for firm fixed effects, the R&D coefficient estimate captures the *cross-sectional* relation between R&D and capital expenditure of different types of firms. The negative coefficient estimate for R&D in Column (3) suggests that firms of the type that spend more on R&D tend to spend less on capital expenditure. However, with the control for firm fixed effects, the R&D coefficient estimate captures the *within-firm* correlation between R&D and capital expenditure, or in other words, the correlation between the change in R&D and the change in capital expenditure of the same firm. The positive coefficient estimate for R&D in Column (5) suggests that a firm that increases more of its R&D expenditure also spends more on capital expenditure in the subsequent year. It is consistent with that R&D expenses create future investment opportunities, which in turn spur the need for more capital expenditure.

In short, with R&D taken as an example, the relation between intangible investment and capital expenditure should not be simplified as substitutes to each other. They play different roles in a firm's production and sometimes are complements to each other. These results have important implications on how we think about and measure corporate investment. It is an oversimplification to sum up capital expenditure and intangible investment as the total investment of a firm. It could be more informative to examine separately the different components of the investment.

5.3.2. Measure investment in intangible capital

How can we measure a firm's investment in intangible capital? Although there seems to be a consensus on the increasing importance of intangible capital, there is still short of a consensus on a precise measure of intangible capital. Unlike investment in fixed assets which is clearly captured by capital expenditure reported in the accounting statements, firms do not explicitly report their investment in intangible capital except for R&D.[37] Moreover, intangible capital has a broad coverage and some of the components can be very subtle. For example, it's difficult to decompose expenses on employees into the part used to hire regular labor and the part that is used to increase production efficiency such as job training, and even harder, how much of an employee's salary is paid to acquire "extra" human capital.

Some recent studies take R&D as investment in knowledge capital and a fraction of SG&A (Selling, General and Administrative Expenses) as investment in organization capital that includes human capital, business process systems, brand recognition and development, and customer relationship, etc., and use the sum of these two as the investment in intangible capital (e.g., Lev and Radhakrishnan, 2005; Corrado, Hulten, and Sichel, 2009; Corrado and Hulten, 2010; Eisfeldt and Papanikolaou, 2013, 2014; Falato, Kadyrzhanove, and Sim, 2014; Peters and Taylor, 2017).[38] The common practice is to assume an *arbitrary but constant* fraction of a firm's SG&A (after filtering out R&D) as its investment in organization capital, e.g., 20% in Corrado, Hulten, and Sichel (2009) and Falato, Kadyrzhanove, and Sim (2014) and 30% in Eisfeldt and Papanikolaou (2014) and Peters and Taylor (2017). This arbitrary discretion inevitably introduces measurement errors, especially given the facts that firms and industries vary in their accounting practices on SG&A expenditures and even the same component, e.g., marketing expenses, may have distinct impact on the productivity of different firms. To mitigate the influence of the measurement errors, some studies in the literature make various adjustments within and/or across industries. For example, in examining the value implication of organization capital, Eisfeldt and Papanikolaou (2013) rank firms within the same industry based on their estimated organization capital and then study the cross-sectional relation between the within-industry relative rank (instead of the estimated value) and future stock returns. Industry-fixed effect is of course another common treatment.

[37] In fact, even R&D is strategically (not) reported for purposes (Koh and Reeb, 2015).

[38] SG&A expenditures typically include maintenance outlays that support current-period operations and profits (e.g., shop rents, delivery costs, sales commissions, etc.) and investment outlays that are to increase future cash flows (Dichev and Tang, 2008; Banker, Huang, and Natarajan, 2011). Thus, not all SG&A expenditures constitute investment in intangibles, and only an arbitrary fraction of SG&A has been used in estimating organization capital.

These existing approaches of estimating intangible investment, though useful in *cross-sectional* studies, are inappropriate to examine the *time-series* behavior of corporate investment in intangibles.[39] This ad hoc approach of taking a *constant* fraction of SG&A imposes a serious issue. Intangible capital becomes more important in firm production over time, and its role also differs in firms and industries of different types. Taking a constant fraction of SG&A uniformly for all firms throughout the long sample period ignores the time-series change in the production technology and its distinct influences across firms and industries. There are neither theoretical nor empirical justifications on what fractions of SG&A shall be taken for different firms at different times. Therefore, it is inappropriate to examine the *time-series* behavior of intangible investment based on the sum of R&D and a *constant* fraction of SG&A as the measure.

Nevertheless, to satisfy one's curiosity, we follow Peters and Taylor's (2017) method and use the sum of R&D and 30% of SG&A as the measure for intangible investment. Figure 8 plots the time-series of intangible investment and the total investment that is constructed as a simple sum of capital expenditure and the estimated intangible investment. There are two important observations. First, the intangible investment based on the Peters and Taylor's approach does not show an increasing trend in Panel A. In particular, the aggregate amount of intangible investment decreases over time, which is inconsistent with the conventional belief. Secondly, the so-constructed total investment still declines over time in panel B. This means that the decline in capital expenditure is not replaced by the Peters and Taylor's measure of intangible investment. In other words, one dollar decrease in capital expenditure is not necessarily accompanied by one dollar increase in intangible investment. As discussed in Section 5.3.1, it is not clear whether total investment should increase, or decrease, or stay constant with the increasing importance of intangible investment in firm production. More efforts are warranted in future studies to delineate a firm's investment in intangible capital from its SG&A expenditures. The diverse nature of intangible capital is another factor to be accounted for.

[39] Note that the balance sheet item of intangible *assets* in Figure 2 falls short to capture the intangible *capital* that a firm has accumulated. An acquisition using the purchasing accounting practice is a chance to recognize the target firm's (but still not the acquirer's) intangible capital into the acquirer's balance sheet assets. However, in most cases a firm's broader investment in intangible capital is not captured in the balance sheet under the current accounting practices.

6. Conclusion

U.S. firms have reduced their capital expenditure by more than half since 1980s. The decline is also pervasive: It occurs in almost every industry and is not concentrated in firms with certain characteristics. The decline is not explained by macroeconomic factors, new listing effects, corporate lifecycle, or the time-variation of firm investment opportunities and financial conditions. Firms in economies that are similarly developed as the U.S. have also experienced substantial declines in capital expenditure while firms in the fast-growing emerging economies have not. We argue that technology advance leads to the transformation in firm production technology, as manifested by the increasing importance of intangible capital and less reliance on fixed assets in firm production. This transformation is accompanied by declines in corporate capital expenditure and changes in the composition of corporate investment. There has been an increase in the employment of intangible inputs as well as more well-educated employees in firm production, and the increased use of intangible inputs and high-quality human capital is negatively related to the change in capital expenditure in the cross section of industries. When an investment opportunity arises, firms in early years respond with more investment in fixed assets, but this sensitivity decreases significantly for recent firms. Economic globalization during this period facilitates the transformation in production technology. The transformation brings about profound implications on U.S. firms’ investment decisions and the resulting asset structure.

Our study calls for a more dynamic view on corporate investment and firm production process. It adds to the burgeoning literature on the role of intangible capital in firm production and economic growth by providing micro-level evidence. Our findings could serve as a stepping stone for future analyses on how we measure and think about corporate investment, and given the importance of corporate investment, on how we better understand other aspects of corporate finance as well as the investment-based asset pricing.

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Appendix A: Variable Definitions

Variable	Definitions
Age(CRSP)	Number of years since first appeared in the CRSP dataset.
Adjusted CAPX/AT	The numerator of CAPX/AT is adjusted by the price index of capital goods.
Capital productivity	The ratio of total sales (SALE) to the net property, plant and equipment (PPENT).
CAPX/AT	The ratio of capital expenditure (CAPX) to the book value of total assets at the beginning of the year (AT).
Cash flow (CF/AT)	Measured as the income before depreciation minus interests, taxes and dividends (OIBDP-XINT-TXT-DVC-DVP) to the book value of total assets.
Cash holdings	The ratio of cash holdings (CHE) to the book value of total assets.
redit spread	Difference between BAA- and AAA-rated corporate bond yields (Federal Reserve).
Firm size (log(AT))	The natural log of book value of total assets (AT), adjusted by the CPI.
GDP growth	The percentage change in the nominal GDP from previous year (Bureau of Economic Analysis)
Inflation	Annual percentage change in the consumer price index (Bureau of Labor Statistics).
Investment-grade dummy	Dummy variable that takes the value of one if a firm has a credit rating BBB- or above.
Market leverage (D/V)	The ratio of total debt (DLTT+DLC) to the market value of assets (book value of total assets – book value of equity + market value of equity).
Market-to-book asset ratio (V/AT)	(book value of total assets – book value of equity + market value of equity)/book value of total assets.
Payout ratio	Measured as the sum of dividends and repurchase (DVC+DVP+PRSTKC)/book value of assets.
R&D	The ratio of R&D expenses (XRD) to the book value of total assets.
Rating dummy	Dummy variable that takes the value of one if a firm has a Standard & Poor's domestic long-term issuer credit rating (SPLTICRM) available since 1986.
Recession dummy	Dummy variable that takes the value of one if there are at least 1 month in a year designated as recession by the NBER.
Sales growth	Measured as the percentage change in the sales from previous year.
Short-term rate	Yield on 1-year government bonds (Federal Reserve).
Speculative-grade dummy	Dummy variable that takes the value of one if a firm has a credit rating BB+ or below.
Term spread	Difference between the yield on 10-year government bonds and the yield on 1-year government bonds (Federal Reserve).
Trend	(Year-1979)/1000, where Year is the fiscal year of the observation
Unemployment	Unemployment rate (Bureau of Labor Statistics)

Appendix B: Descriptive statistics of international data

Our international data, obtained from DataStream, include 38 countries in the period 1980-2016 that have at least five years continuous data of at least 50 public-listed firms. Utilities, banks, and financial service firms are excluded. This table reports, respectively, for the 38 countries in the sample, the firm-year observation number, sample period, starting year to have at least 50 firms, and the median and aggregate ratios of capital expenditure to total assets (CAPX/AT). The last column indicates if the country belongs to G7, OECD, or BRICS.

Country	Firm-Year Observations	Sample period	Starting Year with 50+ obs.	Median CAPX/AT	Aggregate CAPX/AT	G7 / OECD / BRICS
Australia	15938	1980-2016	1994	3.882	7.660	OECD
Belgium	1581	1980-2016	1998	4.593	5.036	OECD
Brazil	3408	1987-2016	1998	3.842	7.813	BRICS
Canada	20464	1980-2016	1987	5.028	8.576	G7/OECD
Chile	2271	1985-2016	1998	4.220	4.952	OECD
China	29891	1991-2016	1995	4.112	5.981	BRICS
Denmark	2097	1980-2016	1995	4.501	7.475	OECD
Finland	2244	1980-2016	1996	4.671	5.291	OECD
France	8809	1980-2016	1987	3.391	5.066	G7/OECD
Germany	10192	1980-2016	1986	4.057	5.633	G7/OECD
Greece	2413	1985-2016	2001	2.165	4.907	OECD
Hong Kong	17419	1980-2016	1990	2.516	5.192	
India	24673	1989-2016	1992	4.390	7.628	BRICS
Indonesia	5754	1989-2016	1991	3.579	6.517	
Israel	3349	1992-2016	2001	2.060	4.617	OECD
Italy	3115	1980-2016	1996	2.908	5.439	G7/OECD
Japan	56878	1980-2016	1980	2.532	4.453	G7/OECD
Malaysia	12770	1980-2016	1991	2.543	5.240	
Mexico	1882	1980-2016	1997	4.208	5.993	OECD
Netherland	1920	1980-2016	1992	4.563	5.862	OECD
New Zealand	1323	1980-2016	2004	4.181	7.243	OECD
Norway	2262	1980-2016	1999	4.940	8.592	OECD
Pakistan	2074	1988-2016	1999	4.435	6.879	
Peru	1389	1987-2016	2000	3.489	8.078	
Philippine	2312	1988-2016	1998	2.903	6.109	
Poland	4015	1992-2016	2002	3.765	6.783	OECD
Russia	2833	1996-2016	2004	3.953	8.592	BRICS
Singapore	9215	1980-2016	1992	2.713	7.751	
South Africa	3807	1980-2016	1997	5.131	7.752	BRICS
South Korea	22125	1980-2016	1989	3.316	6.549	OECD
Spain	1934	1980-2016	1996	3.318	6.103	OECD
Sri Lanka	1988	1993-2016	2005	3.607	7.353	
Sweden	4891	1980-2016	1995	2.323	4.683	OECD
Switzerland	3218	1980-2016	1990	3.791	4.453	OECD
Taiwan	23926	1988-2016	1994	2.746	5.938	
Thailand	7709	1987-2016	1991	3.671	6.348	
Turkey	3585	1987-2016	1998	3.582	5.459	OECD
United Kingdom	19239	1980-2016	1980	3.333	5.154	G7/OECD

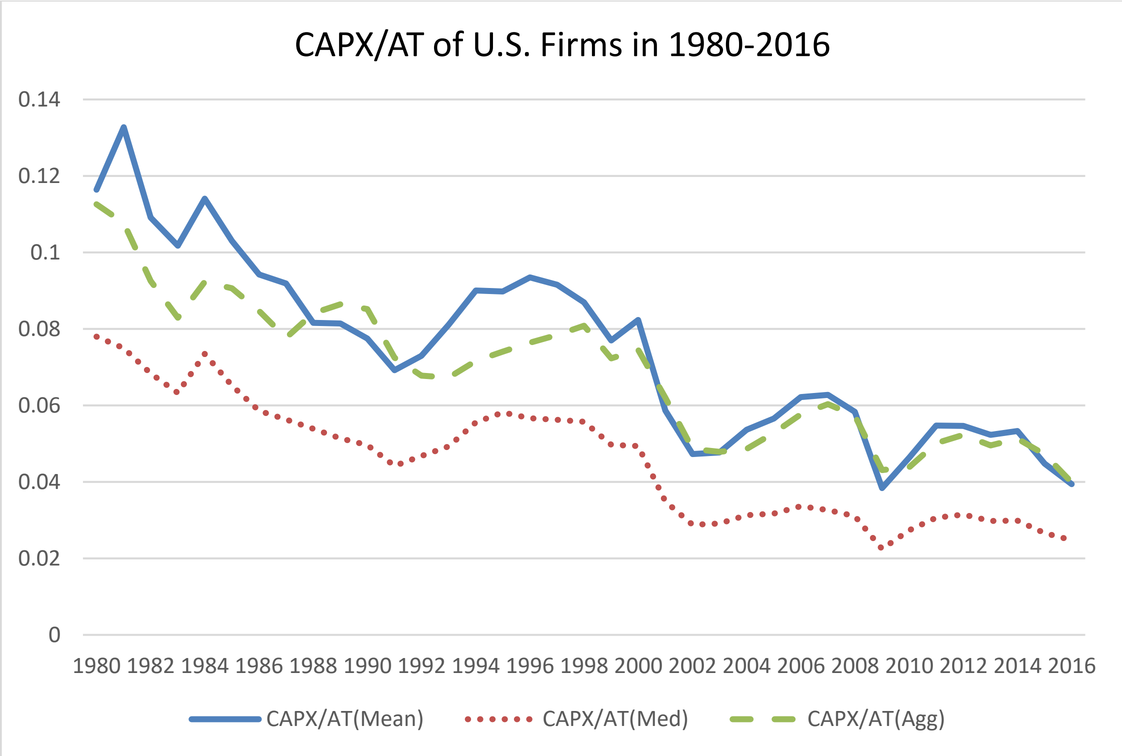


Figure 1
The ratios of capital expenditure to total assets for U.S. firms in 1980-2016

This figure plots the median, mean, aggregate ratios of capital expenditure to total assets (CAPX/AT) for the sample firms during 1980-2016. The denominator, total assets, is measured at the beginning of the year. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms divided by the sum of these firms' dollar total assets at the beginning of the year. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016, with total assets (AT) and capital expenditure (CAPX) information available at the Compustat fundamental annual file. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded.

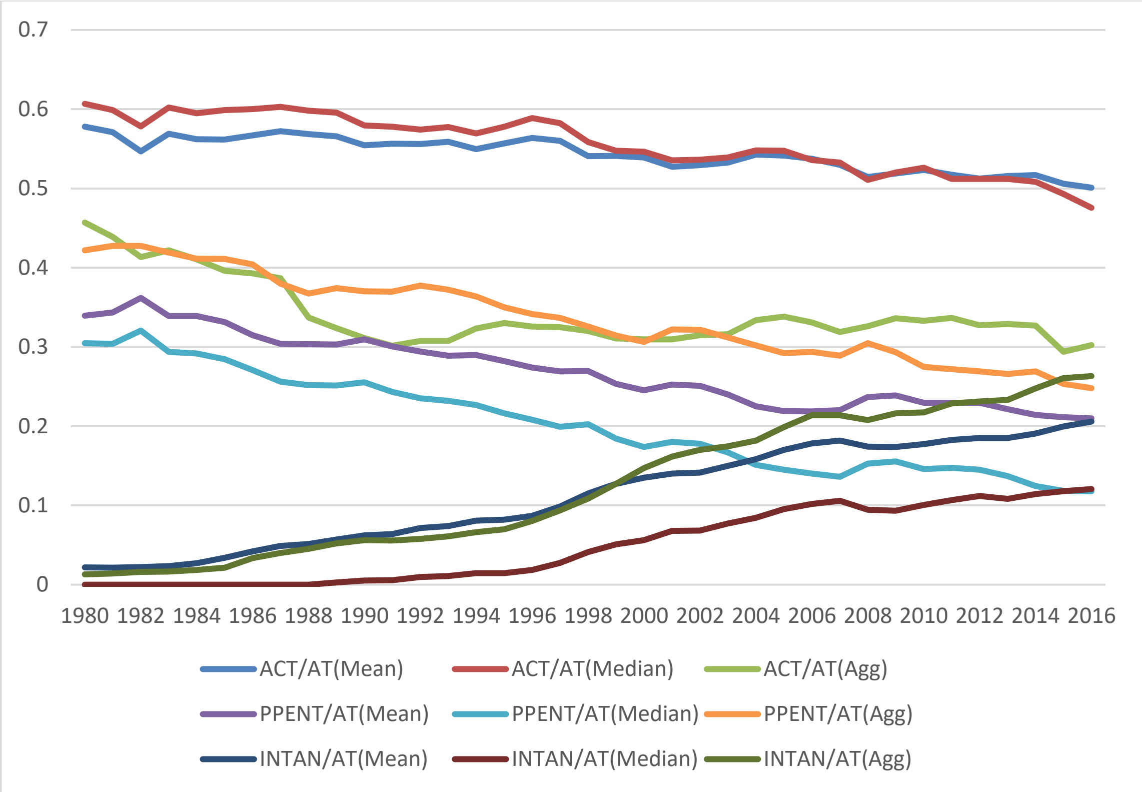


Figure 2
Variation of asset structure in 1980-2016

This figure plots the mean, median, and aggregate ratios of current assets (ACT), net property, plant, and equipment (PPENT), and intangible assets (INTAN) relative to total assets (AT) for the sample.

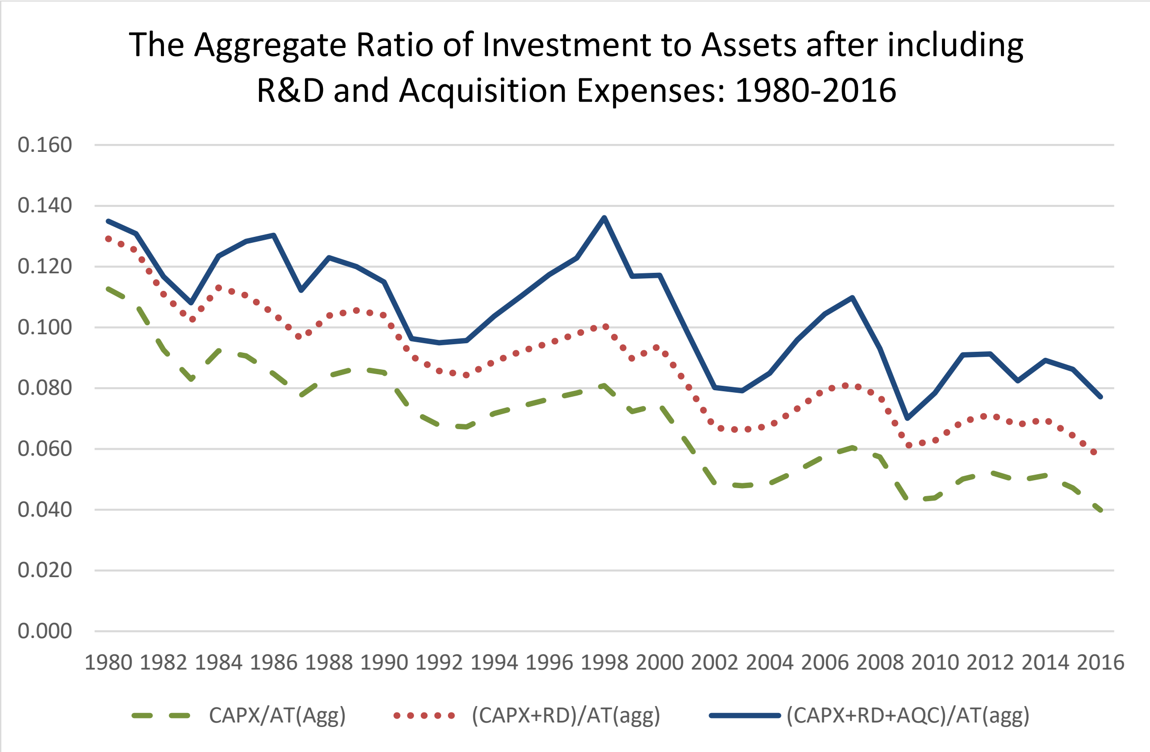
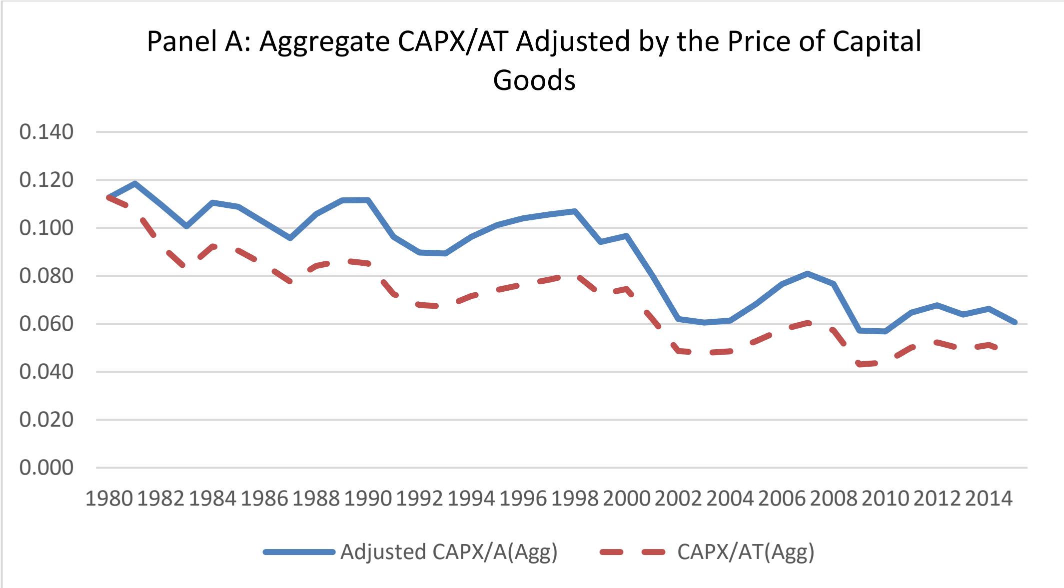


Figure 3
The ratios of alternative investment measures to total assets for U.S. firms in 1980-2016

This figure plots the aggregate ratios of the sum of capital expenditure and R&D or the sum of capital expenditure, R&D and acquisition to total assets (CAPX/AT) for the sample firms during 1980-2016. The denominator, total assets, is measured at the beginning of the year. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms divided by the sum of these firms' dollar total assets at the beginning of the year. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016, with total assets (AT) and capital expenditure (CAPX) information available at the Compustat fundamental annual file. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded.



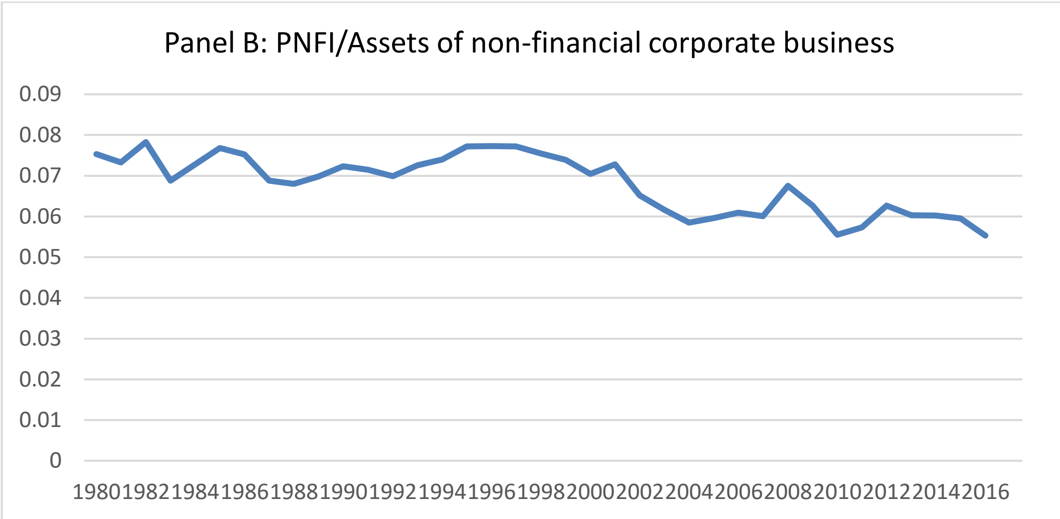


Figure 4
Aggregate ratios of capital investment to total assets: with the adjustment of capital goods price index (Panel A) and with the inclusion of private firms (Panel B)

Panel A of this figure plots two ratios of the aggregate CAPX/AT for U.S. firms in 1980-2016. The numerator of CAPX/AT for the top line is adjusted by the price index of capital goods. The bottom line plots the raw time series, as comparison. Panel B plots the ratio of private non-residential fixed investment (PNFI) to total assets of U.S. non-financial corporate business (including private business). The data are obtained from Federal Reserve.

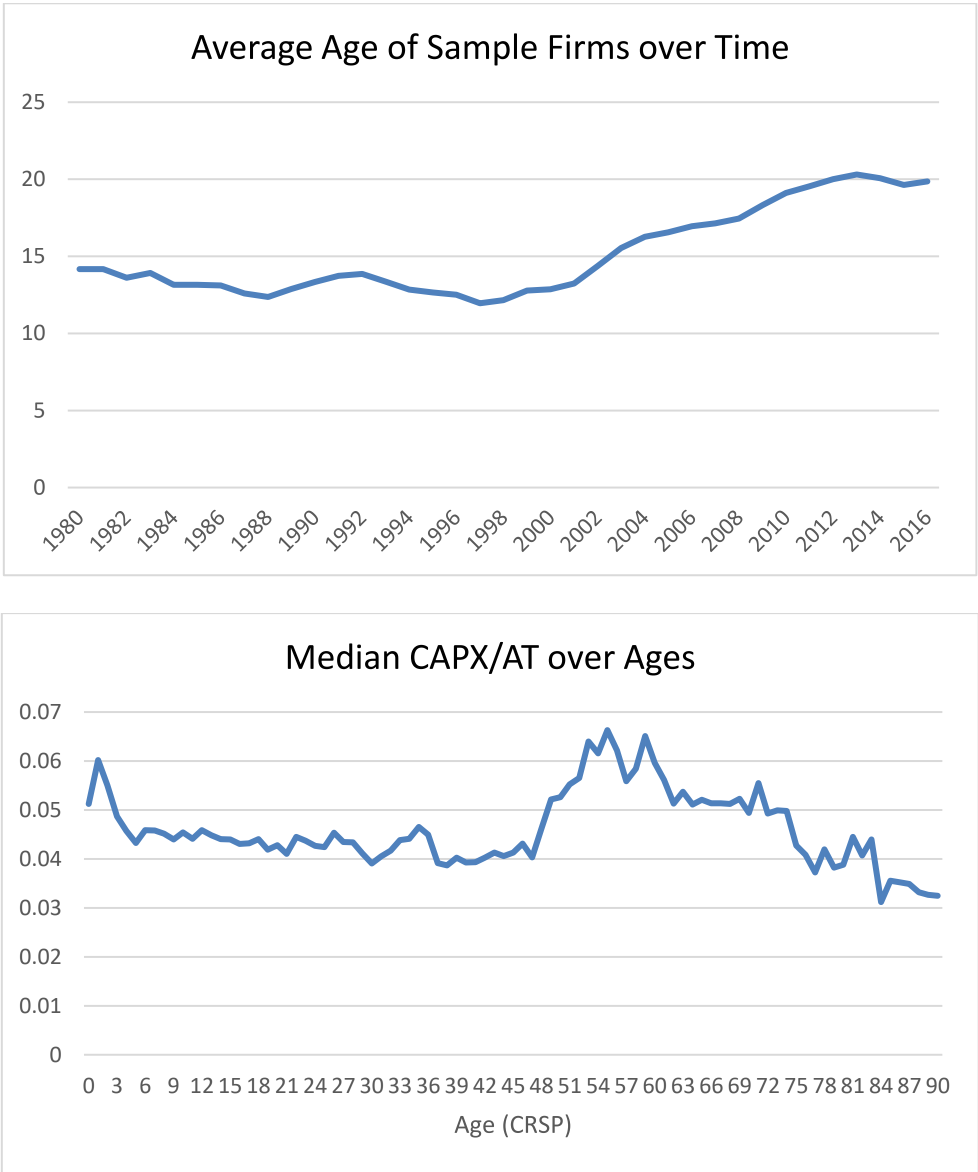


Figure 5
Corporate capital expenditure over the lifecycle

The top panel shows the average age for the sample firms in each year. The age is measured since first included in CRSP. The bottom panel shows the median capital expenditure to assets ratio (CAPX/AT) at different age for the sample firms.

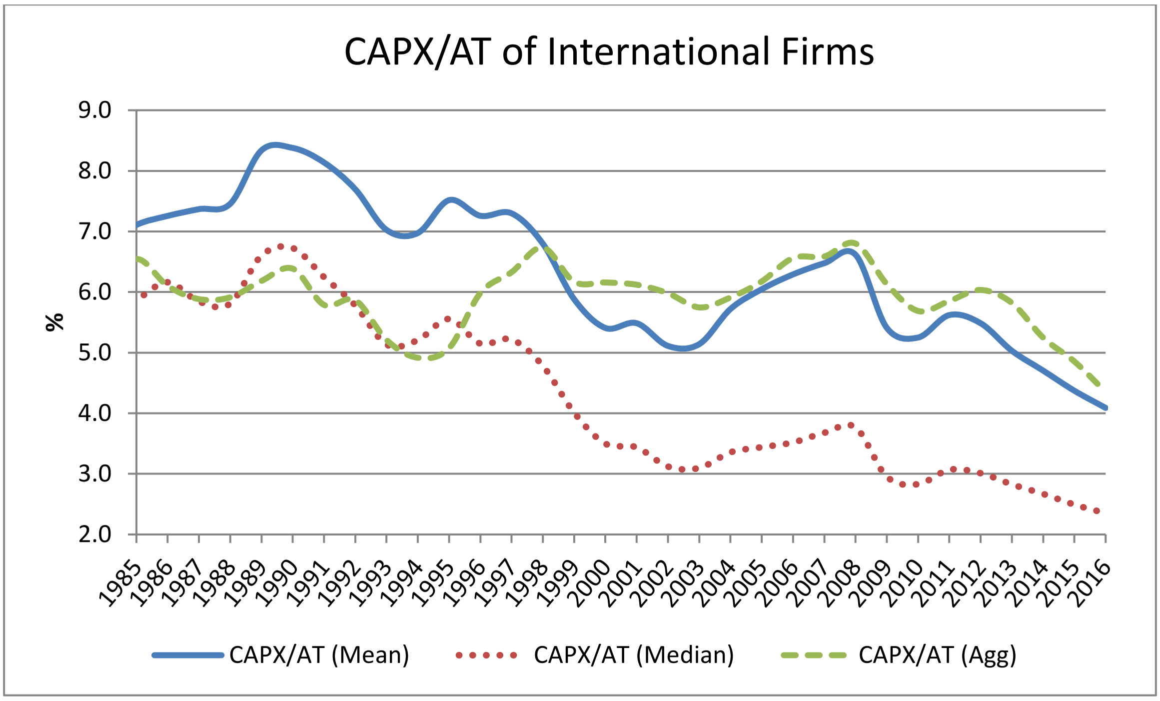


Figure 6
International Evidence

This figure plots the median, mean, and aggregate ratios of capital expenditure to total assets (CAPX/AT) for international firms during 1980-2016. The denominator, total assets, is measured at the beginning of the year. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms divided by the sum of these firms' dollar total assets at the beginning of the year. Our international data, obtained from DataStream for the period 1980-2016, include 38 countries that have at least five years continuous data of at least 50 public-listed firms. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. More detailed information about the data is reported in Appendix B.

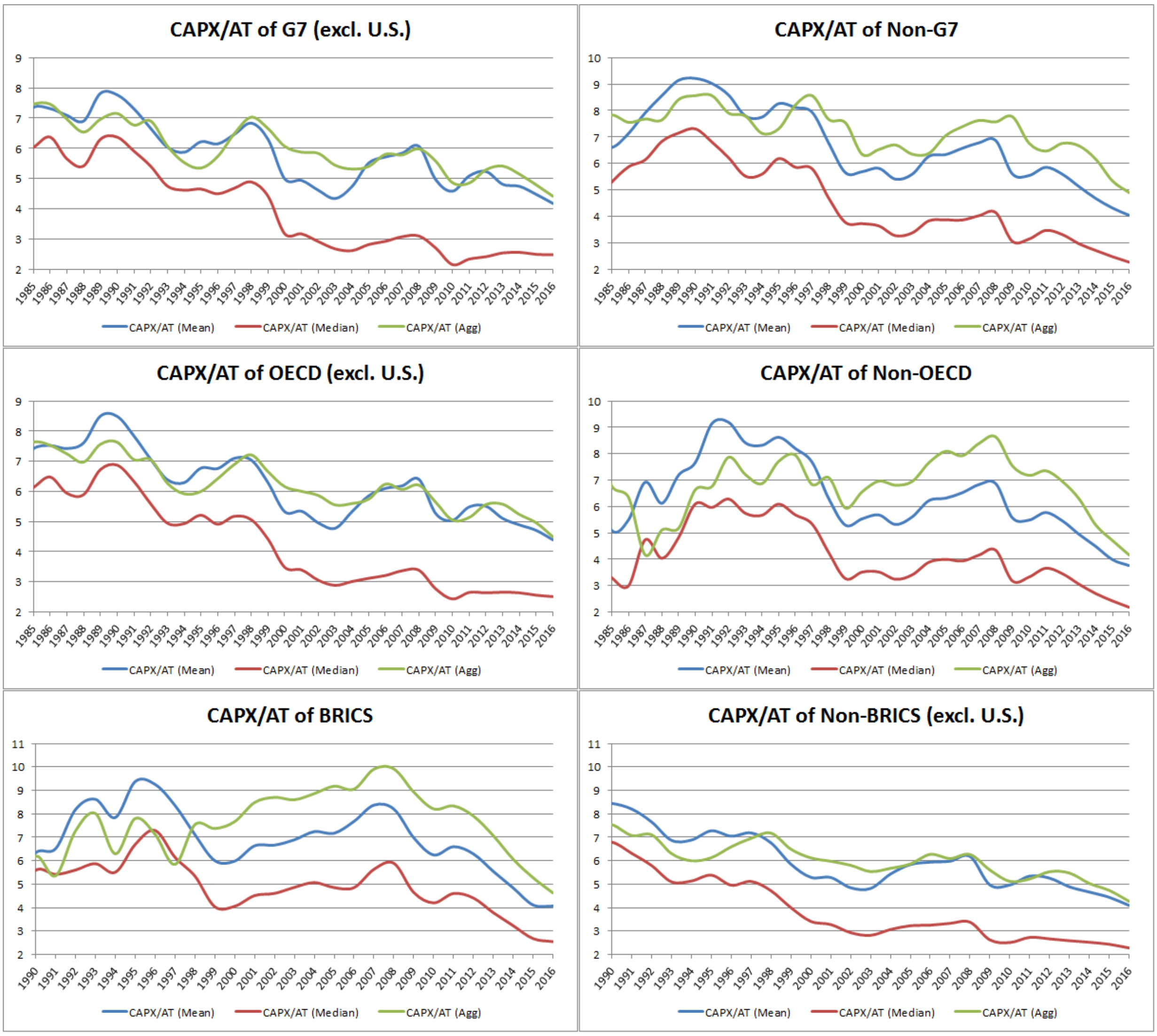
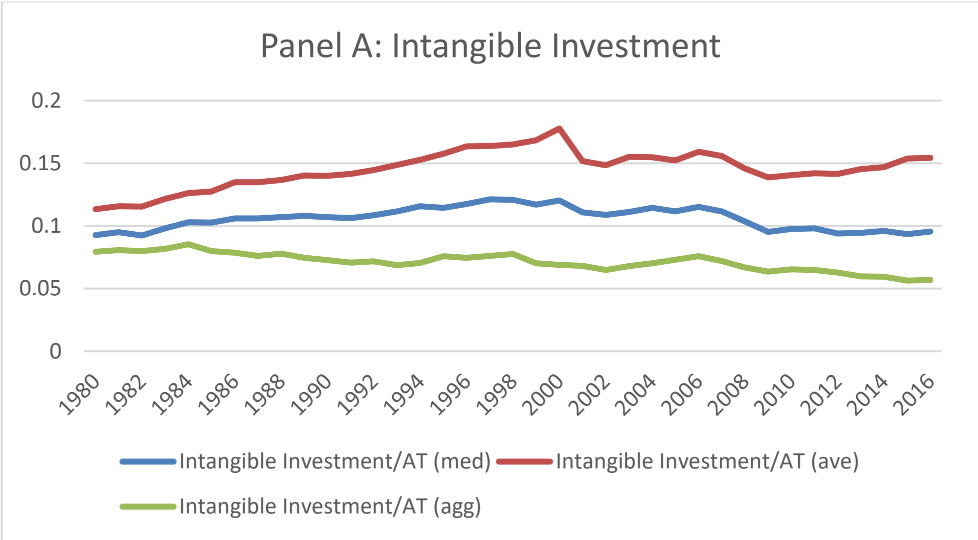


Figure 7
International evidence by groups

This figure plots the median, mean, and aggregate ratios of capital expenditure to total assets (CAPX/AT) in 1980-2016 for international firms in different groups. We group firms from 38 countries based on if the country belongs to G7, OECD, or BRICS countries.



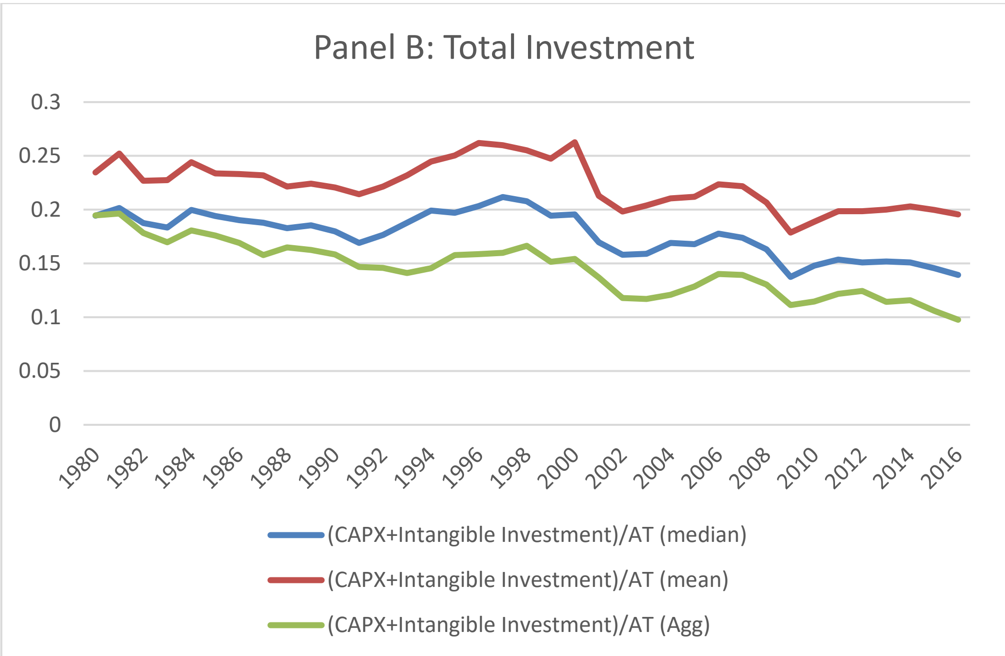


Figure 8
Intangible Investment and Total Investment

This figure plots the median, mean, aggregate ratios of capital intangible investment to total assets (intangible/AT) in Panel A and total investment (sum of intangible investment and CAPX) to total assets in Panel B for the sample firms during 1980-2016. The denominator, total assets, is measured at the beginning of the year. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms divided by the sum of these firms' dollar total assets at the beginning of the year. Intangible investment is defined as the sum of R&D expenses and 30% of SG&A according to Peters and Taylor (2017).

Table 1 - The ratio of capital expenditure to total assets by year: 1980-2016

This table presents the mean, median, and aggregate capital expenditure to total assets ratios (CAPX/AT) for the sample firms from 1980 to 2016. The denominator, total assets, is measured at the beginning of the year. The aggregate ratio is calculated as the sum of capital expenditure across all firms divided by the sum of these firms' total assets at the beginning of the year. Our sample consists of all U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016, and capital expenditure and total assets data available. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. The last three columns report the capital expenditure ratios after adjusting the numerator, CAPX, by the price of capital goods due to technology advance.

		CAPX/AT			Adjusted CAPX/AT		
FYEAR	N	Mean	Median	Aggregate	Mean	Median	Aggregate
1980	3110	0.116	0.078	0.113	0.116	0.078	0.113
1981	3162	0.133	0.075	0.108	0.146	0.082	0.118
1982	3370	0.109	0.068	0.093	0.129	0.081	0.110
1983	3393	0.102	0.063	0.083	0.124	0.077	0.101
1984	3616	0.114	0.073	0.092	0.137	0.088	0.111
1985	3605	0.103	0.065	0.091	0.124	0.078	0.109
1986	3548	0.094	0.059	0.085	0.114	0.071	0.102
1987	3788	0.092	0.056	0.078	0.113	0.070	0.096
1988	3846	0.082	0.054	0.084	0.103	0.068	0.106
1989	3683	0.081	0.051	0.086	0.105	0.066	0.111
1990	3658	0.077	0.050	0.085	0.102	0.065	0.112
1991	3638	0.069	0.044	0.072	0.092	0.059	0.096
1992	3700	0.073	0.047	0.068	0.097	0.062	0.090
1993	3972	0.081	0.049	0.067	0.108	0.065	0.089
1994	4309	0.090	0.056	0.072	0.121	0.075	0.096
1995	4472	0.090	0.058	0.074	0.123	0.079	0.101
1996	4674	0.094	0.057	0.076	0.127	0.077	0.104
1997	4942	0.092	0.056	0.078	0.123	0.076	0.106
1998	4742	0.087	0.056	0.081	0.115	0.074	0.107
1999	4397	0.077	0.050	0.072	0.100	0.065	0.094
2000	4269	0.082	0.049	0.075	0.107	0.064	0.097
2001	4039	0.059	0.035	0.062	0.076	0.045	0.080
2002	3787	0.047	0.029	0.049	0.060	0.037	0.062
2003	3504	0.048	0.029	0.048	0.060	0.037	0.060
2004	3361	0.054	0.031	0.049	0.068	0.039	0.061
2005	3297	0.057	0.032	0.053	0.073	0.041	0.068
2006	3198	0.062	0.034	0.058	0.082	0.045	0.076
2007	3113	0.063	0.033	0.060	0.084	0.044	0.081
2008	3063	0.058	0.031	0.057	0.078	0.041	0.077
2009	2907	0.038	0.022	0.043	0.051	0.030	0.057
2010	2764	0.046	0.027	0.044	0.060	0.035	0.057
2011	2688	0.055	0.031	0.050	0.071	0.040	0.065
2012	2636	0.055	0.031	0.052	0.071	0.041	0.068
2013	2582	0.052	0.030	0.050	0.067	0.038	0.064
2014	2637	0.053	0.030	0.051	0.069	0.039	0.066
2015	2710	0.045	0.027	0.047	0.058	0.034	0.061
2016	2673	0.039	0.025	0.040			
Percent change from 1980 to 2016 (2015)		-66.2%	-68.2%	-64.6%	-50.6%	-56.1%	-46.2%

Table 2 - Time-series regression of capital expenditure

This table reports the Dickey-Fuller test results of the following regression:

$$\Delta\left(\frac{CAPX}{AT}\right)_{t+1} = \alpha + \beta * Trend + \gamma * \left(\frac{CAPX}{AT}\right)_{t} + \theta * \Delta\left(\frac{CAPX}{AT}\right)_{t} + \varepsilon.$$

The dependent variable is the change in the capital expenditure ratio (CAPX/AT) between fiscal year t+1 and t. The independent variables include the time trend variable (Trend), the CAPX/AT in fiscal year t, and the lagged change in the capital expenditure ratios. The regressions in Panel A are respectively performed on the yearly median, mean, and aggregate ratios of capital expenditure to total assets. The regressions in Panel B include macroeconomic variables including changes in GDP growth rates, credit spreads, short-term rates, and term spreads. The dependent variable is the change in the aggregate ratio of CAPX/AT. Both tables report the regression coefficient estimates and the associated *t*-statistics in parentheses. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively. Note the significance test for γ is based on the Dickey-Fuller unit root test critical values, -3.22 for 10%, -3.57 for 5%, and -4.31 for 1%. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded.

Panel A: Testing trend in capital expenditure

	(1) Mean	(2) Median	(3) Aggregate
Trend	-0.415**	-0.919***	-0.876***
	(-2.29)	(-2.97)	(-4.08)
CAPX/AT(t)	-0.325	-0.464	-0.560***
	(-2.69)	(-3.21)	(-4.60)
Δ CAPX/AT(t)	0.241	0.247	0.500***
	(1.45)	(1.48)	(3.52)
Constant	0.022**	0.052***	0.055***
	(2.43)	(3.08)	(4.36)
Observations	37	37	37
R-square	0.119	0.170	0.372

Panel B: Trend test with macroeconomic variables

	(1)	(2)	(3)	(4)
Trend	-0.716***	-0.833***	-0.695***	-0.626***
	(-3.67)	(-3.63)	(-3.80)	(-2.93)
CAPX/AT(t)	-0.450**	-0.533**	-0.445**	-0.388
	(-4.00)	(-4.05)	(-4.26)	(-3.09)
Δ CAPX/AT(t)	0.658***	0.527***	0.353***	0.340**
	(4.92)	(3.49)	(2.88)	(2.42)
Δ GDP Growth	0.116***			
	(3.28)			
Δ Credit Spread		-0.002		
		(-0.58)		
Δ Short Term Rate			0.002***	
			(4.06)	
Δ Term Spread				-0.003***
				(-2.86)
Constant	0.045***	0.052***	0.044***	0.038***
	(3.88)	(3.86)	(4.07)	(2.96)
Observations	37	37	37	37
R-square	0.515	0.359	0.573	0.484

Table 3 - Industry composition and industry capital expenditure ratios

This table reports the number of firms, the percentage of the industry assets relative to the total assets of all firms in the sample, and the aggregate capital expenditure ratio of each industry in 1980 and 2016. The aggregate capital expenditure ratio (CAPX/AT) is calculated as the sum of dollar capital expenditure across all firms in the industry divided by the sum of these firms' dollar total assets at the beginning of the year. The last two columns, respectively, use the industry weights in 2016 and the industry capital expenditure ratios in 1980, and the industry weights in 1980 and the industry capital expenditure ratios in 2016 to compute the aggregate capital expenditure ratios (as reported in the last row of these two columns). Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded.

	Num. of Firms		%Assets			CAPX/AT (aggregate)			%Assets(2016) *CAPX/AT(1980)	%Assets(1980) *CAPX/AT(2016)
Industry	1980	2016	1980	2016	change	1980	2016	change		
Agriculture	17	8	0.20%	0.11%	-0.09%	0.0782	0.0327	-0.0455	0.0001	0.0001
Aircraft	29	18	2.24%	2.30%	0.06%	0.0892	0.0230	-0.0662	0.0021	0.0005
Apparel	73	24	0.99%	0.64%	-0.35%	0.0576	0.0420	-0.0157	0.0004	0.0004
Automobiles and Trucks	66	47	5.00%	3.25%	-1.75%	0.0857	0.0447	-0.0410	0.0028	0.0022
Beer & Liquor	16	10	0.69%	0.32%	-0.37%	0.1268	0.0443	-0.0825	0.0004	0.0003
Business Services	160	253	2.00%	8.11%	6.11%	0.0713	0.0247	-0.0467	0.0058	0.0005
Business Supplies	44	27	2.68%	0.81%	-1.87%	0.1475	0.0508	-0.0967	0.0012	0.0014
Candy & Soda	17	10	0.73%	1.60%	0.87%	0.1286	0.0326	-0.0959	0.0021	0.0002
Chemicals	84	63	6.05%	3.38%	-2.67%	0.1302	0.0449	-0.0853	0.0044	0.0027
Coal	7	3	0.31%	0.07%	-0.24%	0.1640	0.0214	-0.1425	0.0001	0.0001
Communication	36	80	2.25%	7.58%	5.33%	0.1386	0.0443	-0.0943	0.0105	0.0010
Computer Software	14	138	0.02%	4.37%	4.35%	0.2102	0.0307	-0.1795	0.0092	0.0000
Computers	84	49	2.79%	2.57%	-0.22%	0.1229	0.0220	-0.1009	0.0032	0.0006
Construction	43	36	0.74%	0.95%	0.21%	0.0876	0.0128	-0.0747	0.0008	0.0001
Construction Materials	183	38	3.92%	0.64%	-3.28%	0.1013	0.0344	-0.0669	0.0007	0.0014
Consumer Goods	125	37	4.61%	1.86%	-2.75%	0.0973	0.0377	-0.0597	0.0018	0.0017
Defense	9	6	0.99%	0.47%	-0.52%	0.0931	0.0231	-0.0700	0.0004	0.0002
Electrical Equipment	51	39	1.17%	0.55%	-0.62%	0.0851	0.0276	-0.0574	0.0005	0.0003
Electronic Equipment	162	143	3.24%	4.69%	1.45%	0.1307	0.0353	-0.0954	0.0061	0.0011
Entertainment	30	29	0.59%	0.79%	0.20%	0.1418	0.0637	-0.0781	0.0011	0.0004
Fabricated Products	26	7	0.44%	0.07%	-0.37%	0.0274	0.0307	0.0033	0.0000	0.0001

Food Products	79	39	4.02%	2.37%	-1.65%	0.0807	0.0288	-0.0519	0.0019	0.0012
Healthcare	29	48	0.32%	2.67%	2.35%	0.1514	0.0287	-0.1227	0.0040	0.0001
Machinery	152	85	4.36%	3.90%	-0.45%	0.0956	0.0318	-0.0638	0.0037	0.0014
Measuring and Control Equipment	80	50	0.68%	0.98%	0.30%	0.1162	0.0182	-0.0980	0.0011	0.0001
Medical Equipment	44	92	0.81%	1.88%	1.07%	0.1050	0.0292	-0.0758	0.0020	0.0002
Mining	16	15	1.03%	0.73%	-0.30%	0.1687	0.0640	-0.1047	0.0012	0.0007
Others - Almost Nothing	343	481	1.99%	5.98%	3.99%	0.0861	0.0267	-0.0594	0.0052	0.0005
Personal Services	38	31	0.43%	0.58%	0.15%	0.1488	0.0979	-0.0509	0.0009	0.0004
Petroleum and Natural Gas	177	129	13.67%	9.44%	-4.23%	0.1625	0.0768	-0.0857	0.0153	0.0105
Pharmaceutical Products	43	169	2.84%	5.49%	2.65%	0.0746	0.0224	-0.0522	0.0041	0.0006
Precious Metals	8	8	0.04%	0.26%	0.22%	0.1067	0.0484	-0.0583	0.0003	0.0000
Printing and Publishing	44	25	1.03%	0.80%	-0.24%	0.0920	0.0114	-0.0806	0.0007	0.0001
Recreation	37	20	0.52%	0.22%	-0.31%	0.0994	0.0421	-0.0573	0.0002	0.0002
Restaurants, Hotels, Motels	68	53	1.17%	1.59%	0.42%	0.1569	0.0534	-0.1035	0.0025	0.0006
Retail	220	139	6.54%	7.29%	0.75%	0.0949	0.0468	-0.0481	0.0069	0.0031
Rubber and Plastic Products	43	17	0.44%	0.37%	-0.07%	0.0760	0.0365	-0.0395	0.0003	0.0002
Shipbuilding, Railroad Equipment	6	6	0.51%	0.19%	-0.32%	0.1224	0.0700	-0.0524	0.0002	0.0004
Shipping Containers	40	6	1.93%	0.29%	-1.63%	0.1013	0.0500	-0.0512	0.0003	0.0010
Steel Works	82	29	5.29%	0.85%	-4.44%	0.0910	0.0363	-0.0547	0.0008	0.0019
Textiles	62	9	0.91%	0.12%	-0.80%	0.0779	0.0641	-0.0138	0.0001	0.0006
Tobacco Products	9	6	2.12%	1.09%	-1.03%	0.0796	0.0131	-0.0665	0.0009	0.0003
Transportation	80	57	5.53%	4.52%	-1.01%	0.1455	0.0752	-0.0703	0.0066	0.0042
Wholesale	134	94	2.12%	3.23%	1.11%	0.0688	0.0240	-0.0449	0.0022	0.0005
SUM	3110	2673	100%	100%	0%				**11.51%**	**4.41%**

Table 4 - Capital expenditure by groups of firms

This table reports the time series average by groups of firms of the media capital expenditure ratio (CAPX/AT). The breakpoint for high/low and small/large groups is the yearly 50th percentile of each firm characteristic. We also run regressions as in equation (1) to test the time trend for each group. The last two columns report the coefficient estimates for the time trend variable (inflated by 1000). Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. Variable definitions are available in the appendix.

Characteristic Variables	Subsample	1980-1984	1985-1989	1990-1994	1995-1999	2000-2004	2005-2009	2010-2016	1980-2016	Trend
Market to Book Asset	Low	0.055	0.047	0.040	0.047	0.029	0.027	0.027	0.038	-0.411**
	High	0.095	0.069	0.061	0.065	0.040	0.033	0.030	0.053	-0.511*
Sales Growth	Low	0.054	0.049	0.041	0.047	0.029	0.027	0.027	0.038	-0.361**
	High	0.088	0.065	0.058	0.063	0.040	0.034	0.032	0.052	-0.410*
Free Cash Flow	Small	0.050	0.038	0.032	0.038	0.023	0.021	0.021	0.031	-0.246*
	Large	0.094	0.080	0.070	0.074	0.049	0.045	0.039	0.064	-0.844***
Assets	Low	0.065	0.047	0.040	0.046	0.028	0.024	0.023	0.037	-0.343**
	High	0.076	0.065	0.058	0.063	0.040	0.036	0.034	0.052	-0.595**
Payout Ratio	Low	0.071	0.050	0.043	0.052	0.032	0.026	0.026	0.040	-0.345*
	High	0.072	0.062	0.054	0.058	0.036	0.034	0.031	0.049	-0.564***
Rating Dummy	Unrated		0.054	0.047	0.054	0.034	0.030	0.028	0.042	-0.347*
	Rated		0.069	0.062	0.063	0.040	0.038	0.035	0.048	-0.518**
Rating Grades	Speculative grade		0.054	0.049	0.057	0.036	0.036	0.037	0.042	-0.330*
	Investment grade		0.079	0.069	0.068	0.044	0.040	0.033	0.053	-0.637**
Leverage	Low	0.084	0.063	0.054	0.056	0.033	0.027	0.026	0.047	-0.540**
	High	0.061	0.052	0.044	0.054	0.035	0.034	0.031	0.043	-0.359**
Cash Holdings	Low	0.067	0.056	0.048	0.057	0.037	0.036	0.033	0.047	-0.401***
	High	0.077	0.059	0.051	0.053	0.031	0.025	0.024	0.043	-0.491*
Capital Productivity	Low	0.100	0.074	0.066	0.074	0.047	0.046	0.043	0.062	-0.544**
	High	0.053	0.045	0.037	0.043	0.026	0.022	0.021	0.033	-0.357**
R&D	Non-R&D Firms	0.073	0.059	0.051	0.062	0.042	0.042	0.037	0.053	-0.413**
	R&D Firms	0.070	0.056	0.048	0.050	0.030	0.024	0.024	0.039	-0.426**
Acquisition	Non-Acquirer	0.065	0.049	0.043	0.051	0.034	0.026	0.021	0.045	-0.465**
	Acquirer	0.074	0.060	0.051	0.056	0.034	0.030	0.030	0.045	-0.420**

Table 5 – Cross-sectional regressions of capital expenditure on firm characteristics

This table reports the estimates of OLS regressions of capital expenditure ratio (CAPX/AT). The explanatory variables consist of a time trend variable and firm characteristics including size measured as the log of total assets (log(AT)), market-to-book ratio of assets (V/AT), cash flow to assets ratio (CF/AT), market leverage (D/V), capital productivity measured as sales divided by the gross property, plant and equipment (Sales/PPEGT), R&D expenses to assets ratio (RD/AT), payout to assets ratio (Payout/AT), and sales growth. Firm characteristics are lagged by one fiscal year. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. Variable definitions are available in the appendix. The table reports the regression coefficient estimates and the robust t-statistics adjusted for firm-leveling clustering in parentheses. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

	(1)	(2)	(3)	(4)	(5)
VARIABLES	OLS	OLS	OLS	Industry Fixed Effects	Firm fixed Effects
Trend	-1.938***	-1.951***	-1.390***	-1.502***	-1.525***
	(-37.53)	(-37.00)	(-26.34)	(-9.33)	(-23.59)
log(AT)		-0.001**	-0.001***	-0.001**	-0.012***
		(-2.19)	(-2.77)	(-2.33)	(-14.00)
V/AT		0.010***	0.009***	0.009***	0.008***
		(29.17)	(22.68)	(8.10)	(18.91)
CF/AT		0.083***	0.070***	0.081***	0.049***
		(30.11)	(20.40)	(7.23)	(14.36)
D/V			-0.026***	-0.044***	-0.123***
			(-7.78)	(-4.64)	(-30.95)
Sales/PPEGT			-0.001***	-0.001***	-0.000***
			(-28.72)	(-8.54)	(-10.04)
RD/AT			-0.094***	-0.000	0.020***
			(-15.63)	(-0.03)	(2.93)
Payout/AT			-0.088***	-0.071***	-0.016**
			(-10.86)	(-3.17)	(-2.54)
Sales growth			0.014***	0.012***	0.007***
			(17.34)	(4.24)	(9.62)
Constant	0.112***	0.095***	0.104***	0.105***	0.167***
	(94.35)	(51.82)	(51.24)	(26.03)	(39.99)
Observations	125,370	125,370	111,647	111,647	111,647
R-square	0.039	0.082	0.132	0.239	0.564

Table 6 - Cross-sectional regressions of capital expenditure with new listing groups

This table reports the estimates of OLS regressions of capital expenditure ratio (CAPX/AT). The explanatory variables consist of a time trend variable and firm characteristics including size measured as the log of total assets (log(A)), market-to-book ratio of assets (V/AT), cash flow to assets ratio (CF/AT), market leverage (D/V), capital productivity measured as sales divided by the gross property, plant and equipment (Sales/PPEGT), R&D expenses to assets ratio (RD/AT), credit rating dummy, payout to assets ratio (Payout/AT), sales growth, a set of listing dummy variables and firm age. Firm characteristics are lagged by one fiscal year. Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. Variable definitions are available in the appendix. The table reports the regression coefficient estimates and the robust t-statistics adjusted for firm-leveling clustering in parentheses. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

	(1)	(2)	(3)	(4)
Trend	-1.818***	-2.457***	-2.389***	-2.232***
	(-34.86)	(-39.86)	(-12.58)	(-13.53)
list_1950		0.005	-0.003	0.003
		(1.00)	(-0.51)	(0.55)
list_1960		-0.001	-0.007	-0.002
		(-0.42)	(-1.01)	(-0.25)
list_1970		0.014***	0.006	0.006
		(5.71)	(0.75)	(0.90)
list_1980		0.025***	0.014	0.014
		(10.38)	(1.37)	(1.57)
list_1990		0.029***	0.016	0.020*
		(12.65)	(1.35)	(1.95)
list_2000		0.035***	0.023*	0.021*
		(12.50)	(1.70)	(1.79)
log(AT)			0.002***	-0.000
			(4.46)	(-0.61)
V/AT			0.010***	0.011***
			(27.86)	(31.48)
CF/AT			0.082***	0.076***
			(30.06)	(29.64)
Age(CRSP)	-0.593***		-0.299	-0.134
	(-16.51)		(-1.63)	(-0.83)
Constant	0.119***	0.101***	0.086***	0.048***
	(94.78)	(49.92)	(9.33)	(4.85)
Industry Dummies	No	No	No	Yes
Observations	125,370	125,370	125,370	125,370
R-square	0.046	0.048	0.091	0.210

Table 7 – Change in production technology and the decline in capital expenditure

This table reports the industry-level panel regression results of the change in capital expenditure on the changes in some measures of production technology. Industries are classified into Fama-French 49 industries. The change in capital expenditure is the change in the aggregate ratio of capital expenditure to total assets in an industry. In Panel A, the explanatory variables are, respectively, the changes in the ratio of materials, purchased services, energy, and employee compensation to an industry's total inputs. An industry's total inputs are measured as the sum of materials, purchased services, energy, and employee compensation. The annual data on each of the inputs – materials, purchased services, and energy – are available since 1997. The data on employee compensation and the sum of material, purchased services, and energy are available since 1987. In Panel B, the explanatory variables are, respectively, the changes in the percentage of employees with high school degree or college degree (at least 4-year college education), or high skill employees. High skill employees are defined as those with more than 5 years of college education. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

Panel A:

	(1)	(2)	(3)	(4)	(5)
Change in materials	0.120***				
	(3.50)				
Change in purchased services		-0.094*			-0.099*
		(-1.91)			(-1.78)
Change in energy			0.273**		0.134
			(2.64)		(1.25)
Change in employee compensation				-0.183***	-0.145***
				(-4.81)	(-4.15)
Constant	-0.005***	-0.005***	-0.006***	-0.006***	-0.005***
	(-6.29)	(-6.63)	(-6.97)	(-6.39)	(-6.41)
Other Controls	Yes	Yes	Yes	Yes	Yes
Observations	836	836	836	1,276	836
R-square	0.155	0.142	0.153	0.125	0.176

Panel B:

	(1)	(2)	(3)	(4)	(5)	(6)
Change in the % of employees with high school degree	-0.145***	-0.080***				
	(-5.11)	(-3.29)				
Change in the % of employees with college degree			-0.224***	-0.130***		
			(-4.84)	(-3.78)		
Change in the % of high skill employees					-0.243***	-0.148***
					(-3.58)	(-2.80)
Constant	-0.001***	-0.005***	-0.001**	-0.005***	-0.001***	-0.005***
	(-2.94)	(-4.41)	(-2.24)	(-4.33)	(-6.55)	(-4.78)
Other Controls	No	Yes	No	Yes	No	Yes
Observations	774	774	774	774	774	774
R-square	0.019	0.259	0.048	0.269	0.014	0.258

Table 8 – International evidence of trend in capital expenditure by countries

This table reports the Dickey-Fuller test results of the following regression for firms in each country: $\Delta\left(\frac{CAPX}{AT}\right)_{t+1} = \alpha + \beta * Trend + \gamma * \left(\frac{CAPX}{AT}\right)_t + \theta * \Delta\left(\frac{CAPX}{AT}\right)_t + \varepsilon$. The dependent variable is the change in CAPX/AT between fiscal year t+1 and t. The independent variables include the time trend variable (Trend), the CAPX/AT in fiscal year t, and the lagged change in CAPX/AT. The regressions are run separately for each country on its yearly median, mean, and aggregate capital expenditure ratios. The aggregate ratio is calculated as the sum of dollar capital expenditure across all firms in the country divided by the sum of these firms' dollar total assets at the beginning of the year. We require the country to have at least 12 years qualified data and 31 out of the 38 countries are qualified. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. The coefficient on Trend is inflated by 1000. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

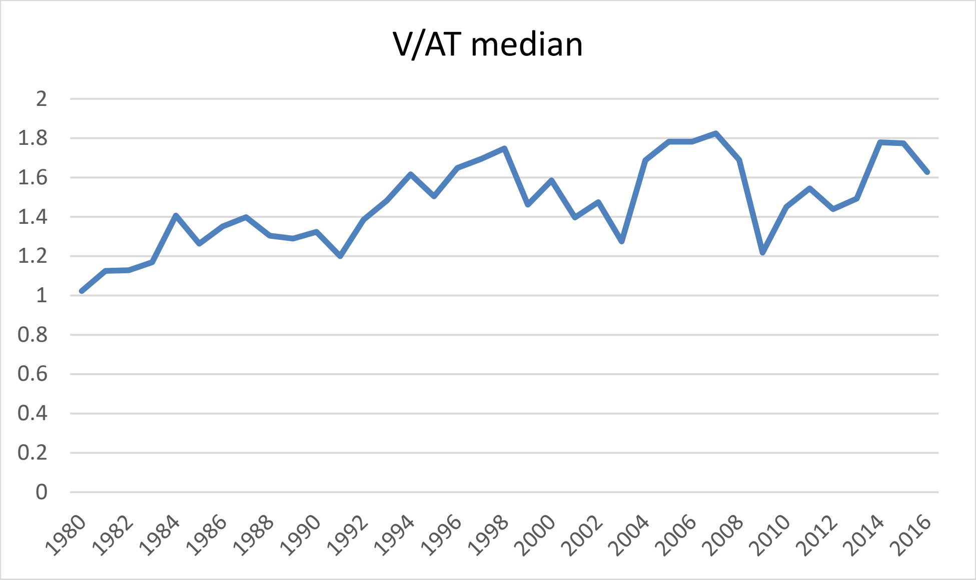
	CAPX/AT (median)		CAPX/AT (mean)		CAPX/AT (aggregate)	
Country	Time Trend Coefficient	t-stat	Time Trend Coefficient	t-stat	Time Trend Coefficient	t-stat
Australia	-0.033	-1.30	0.007	0.30	-0.031*	-1.72
Belgium	-0.077***	-3.21	-0.057***	-2.88	-0.084**	-2.31
Brazil	-0.100***	-3.63	-0.087**	-2.85	-0.129	-1.99*
Canada	-0.054**	-2.93	0.029	1.17	0.008	-0.42
Chile	-0.083	-1.06	-0.094*	-1.77	-0.108*	-1.96
China	-0.034	-1.72	-0.048	-1.54	-0.074*	-1.95
Denmark	-0.173***	-3.51	-0.128***	-2.89	-0.028	-1.47
Finland	-0.257***	-5.20	-0.241***	-5.20	-0.267***	-5.02
France	-0.079***	-2.88	-0.072***	-3.92	-0.082***	-3.10
Germany	-0.060**	-2.30	-0.056**	-2.49	-0.063***	-3.16
Hong Kong	-0.161***	-4.80	-0.204***	-4.14	-0.024	-1.39
India	-0.066*	-1.87	-0.050	-1.25	-0.020	-0.37
Indonesia	-0.003	-0.07	-0.002	-0.04	-0.019	-0.31
Italy	-0.084***	-4.46	-0.090***	-4.72	-0.028	-1.69
Japan	-0.059*	-1.92	-0.078**	-2.74	-0.032***	-2.92
Malaysia	-0.020	-1.64	-0.023	-1.30	-0.015	-0.71
Mexico	-0.024	-1.25	-0.034	-1.67	-0.036	-1.51
Netherland	-0.065***	-3.63	-0.088***	-3.51	-0.060***	-3.45
Norway	-0.259**	-2.72	-0.314***	-4.10	-0.104*	-1.83
Pakistan	-0.031	-0.78	-0.040	-0.93	-0.095	-1.30
Philippine	-0.095	-0.85	-0.014	-0.16	-0.181	-1.72
Singapore	-0.021	-1.30	-0.030	-1.43	-0.128***	-2.85
South Africa	-0.081**	-2.23	-0.061***	-3.41	0.001	0.05
South Korea	-0.167***	-2.93	-0.087**	-2.56	-0.098**	-2.53
Spain	-0.084**	-2.72	-0.075***	-2.96	-0.149***	-2.91
Sweden	-0.092***	-3.15	-0.069***	-3.01	-0.037**	-2.19
Switzerland	-0.051***	-3.12	-0.058***	-3.28	-0.037***	-3.35
Taiwan	-0.153***	-2.92	-0.166***	-3.77	-0.117**	-2.56
Thailand	-0.027	-0.62	-0.027	-0.79	-0.049	-0.84
Turkey	-0.063	-0.52	-0.176	-1.52	-0.172	-1.84
United Kingdom	-0.071**	-2.61	-0.089***	-3.58	-0.090**	-2.76
No. (%) of declines	31/31	(100.0%)	29/31	(93.6%)	29/31	(93.6%)
No. (%) of significant declines	20/31	(64.5%)	19/31	(61.3%)	17/31	(54.8%)

Table 9 – The sensitivities of capital expenditure to firm characteristics over time

This table reports the change in the sensitivities of capital expenditure ratio (CAPX/AT) to firm characteristics across different time periods. Regressions of the odd models are OLS regressions and those of the even models are Fama and MacBeth regressions. The dependent variable is CAPX/AT, and the explanatory variables consist of a time trend variable and firm characteristics including size measured as the log of total assets (log(AT)), market-to-book ratio of assets (V/AT), and cash flow to assets ratio (CF/AT). Firm characteristics are lagged by one fiscal year. The sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded. Variable definitions are available in the appendix. The tables report the regression coefficient estimates and the robust t-statistics adjusted for firm-leveling clustering in parentheses. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

	(1)	(2)	(3)	(4)
	OLS		EJW (2014)	
VARIABLES	CAPX/AT	CAPX/AT	CAPX/AT	CAPX/AT
log(AT)	-0.003***	-0.004***	0.010***	0.010***
	(-4.60)	(-6.23)	(10.04)	(6.92)
log(AT)*Trend	0.130***	0.151***	-0.360***	-0.344***
	(5.33)	(5.99)	(-8.31)	(-6.23)
CF/AT	0.191***	0.136***	0.451***	0.240***
	(26.05)	(19.66)	(22.26)	(16.45)
CF/AT *Trend	-5.260***	-3.546***	-16.914***	-7.623***
	(-18.75)	(-13.43)	(-19.67)	(-13.27)
V/AT	0.024***		0.116***	
	(25.61)		(23.15)	
V/AT *Trend	-0.759***		-5.225***	
	(-18.70)		(-22.14)	
Total q		0.010***		0.064***
		(16.40)		(13.09)
Total q*Trend		-0.351***		-3.071***
		(-12.50)		(-13.08)
Trend	-1.137***	-2.097***	9.706***	3.790***
	(-7.65)	(-14.32)	(16.41)	(6.93)
Constant	0.076***	0.112***	-0.154***	-0.020
	(24.19)	(37.19)	(-11.87)	(-1.56)
Observations	125,370	124,590	125,370	115375
R-squared	0.100	0.076	0.208	0.157

Internet Appendix



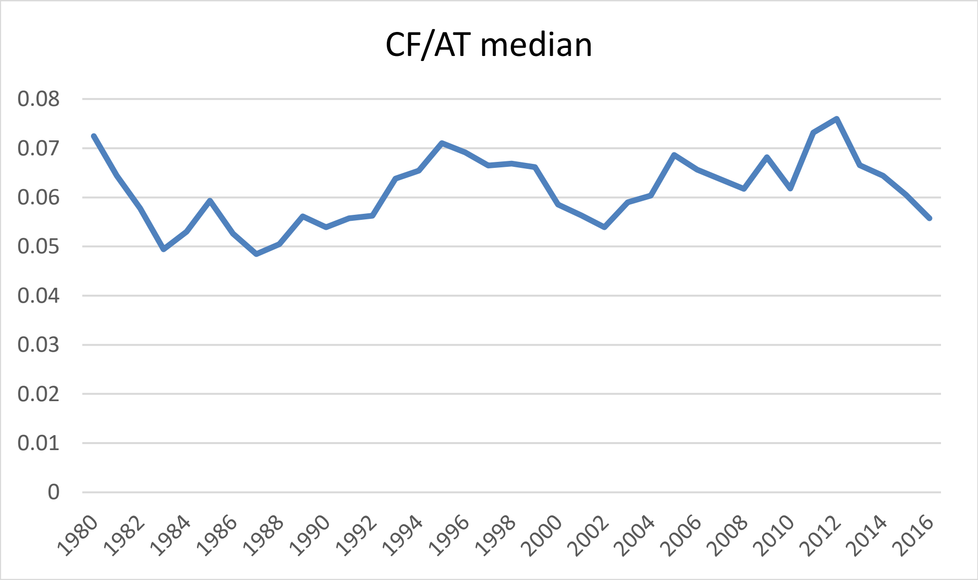


Figure IA.1
Variation of firm characteristics over 1980-2016

The figures plot the medians of market to book asset ratio (V/AT) and cash flow to asset ratio (CF/AT).

Table IA.1 - Industry-level test of time trend in capital expenditure

This table reports the Dickey-Fuller test results of the following regression for each industry: $\Delta\left(\frac{CAPX}{AT}\right)_{t+1} = \alpha + \beta * Trend + \gamma * \left(\frac{CAPX}{AT}\right)_t + \theta * \Delta\left(\frac{CAPX}{AT}\right)_t + \varepsilon.$
The dependent variable is the change in CAPX/AT between fiscal year t+1 and t. The independent variables include the time trend variable (Trend), the CAPX/AT in fiscal year t, and the lagged change in the capital expenditure ratios. The regressions are performed separately for each industry on its yearly median, mean, and aggregate capital expenditure ratios. The aggregate ratio is calculated as the sum of capital expenditure across all firms in the industry divided by the sum of these firms' total assets at the beginning of the year. Industries are classified as in the 49-industry scheme of Fama and French (1997). Our sample consists of U.S. firms with common stocks traded at the NYSE, AMEX, or NASDAQ during the period of 1980-2016. Utilities (SIC codes between 4900 and 5000) and financial firms (SIC codes between 6000 and 7000) are excluded.The coefficient on *Time Trend* is inflated by 1000. Statistical significance of the 1%, 5%, or 10% level is marked by ***, **, and *, respectively.

	CAPX/AT (median)		CAPX/AT (mean)		CAPX/AT (aggregate)	
Industry Name	Time Trend Coefficient	t-stat	Time Trend Coefficient	t-stat	Time Trend Coefficient	t-stat
Agriculture	-0.680*	(-2.01)	-2.419***	(-4.43)	-1.754***	(-3.53)
Aircraft	-0.345	(-1.60)	-0.494*	(-1.84)	-0.507**	(-2.42)
Apparel	-0.018	(-0.23)	-0.282**	(-2.28)	-0.365***	(-2.76)
Automobiles and Trucks	-0.149	(-0.95)	-0.236	(-1.50)	-0.819***	(-4.12)
Beer & Liquor	-0.425	(-1.38)	-0.740**	(-2.06)	-1.213***	(-3.16)
Business Services	-0.399*	(-1.96)	-0.789**	(-2.43)	-0.717**	(-2.51)
Business Supplies	-0.495	(-1.38)	-0.642	(-1.68)	-1.032**	(-2.37)
Candy & Soda	-0.758*	(-1.76)	-1.004**	(-2.41)	-0.961**	(-2.70)
Chemicals	-0.414**	(-2.21)	-0.783***	(-3.07)	-0.591**	(-2.41)
Coal	-0.213	(-0.53)	-1.229*	(-2.03)	-0.176	(-0.46)
Communication	-0.911**	(-2.05)	-1.134**	(-2.19)	-0.531*	(-1.76)
Computer Software	-0.098	(-0.29)	-0.709	(-1.49)	-0.328	(-0.78)
Computers	-0.409*	(-1.95)	-0.594	(-1.56)	-0.936**	(-2.53)
Construction	-0.502***	(-2.79)	-0.756***	(-2.77)	-0.268	(-1.04)
Construction Materials	-0.398**	(-2.33)	-0.497*	(-1.95)	-0.707**	(-2.40)
Consumer Goods	-0.434**	(-2.49)	-0.616***	(-3.19)	-0.955***	(-4.51)
Defence	-1.298***	(-3.20)	-1.137**	(-2.68)	-1.337***	(-3.20)
Electrical Equipment	-0.345**	(-2.20)	-0.701**	(-2.30)	-0.870***	(-2.91)
Electronic Equipment	-0.606**	(-2.64)	-0.869**	(-2.53)	-1.172***	(-3.02)
Entertainment	-0.993**	(-2.15)	-1.860***	(-2.77)	-3.308***	(-3.69)

Fabricated Products	0.158	(0.69)	-0.555*	(-1.92)	0.616*	(1.99)
Food Products	-0.863***	(-2.87)	-0.873***	(-3.26)	-0.718***	(-3.14)
Healthcare	-0.794	(-1.58)	-1.212**	(-2.53)	-0.935**	(-2.12)
Machinery	-0.383**	(-2.58)	-0.630**	(-2.67)	-0.574***	(-3.43)
Measuring and Control Equipment	-0.462**	(-2.07)	-0.976***	(-2.81)	-2.437***	(-4.14)
Medical Equipment	-0.352*	(-1.76)	-0.971**	(-2.40)	-0.966***	(-3.05)
Mining	-0.354	(-0.90)	-1.367***	(-2.84)	-0.325	(-1.10)
Others - Almost Nothing	-0.918***	(-2.84)	-1.417**	(-2.62)	-1.596***	(-3.28)
Personal Services	-0.443*	(-1.82)	-1.260**	(-2.29)	-0.524	(-0.84)
Petroleum and Natural Gas	0.184	(0.22)	-0.303	(-0.36)	0.069	(0.25)
Pharmaceutical Products	-1.867***	(-5.53)	-2.318***	(-4.45)	-0.361**	(-2.69)
Precious Metals	-0.812*	(-1.74)	-2.289**	(-2.51)	-2.234**	(-2.49)
Printing and Publishing	-0.581**	(-2.11)	-0.754***	(-2.86)	-0.410	(-1.56)
Recreation	-0.440**	(-2.65)	-0.912***	(-3.35)	-0.510	(-1.22)
Restaurants, Hotels, Motels	-1.248***	(-3.12)	-1.429***	(-3.12)	-1.641***	(-3.32)
Retail	-0.492***	(-3.16)	-0.675***	(-3.58)	-0.617***	(-3.69)
Rubber and Plastic Products	-0.805***	(-2.83)	-0.991**	(-2.37)	-0.646*	(-1.87)
Shipbuilding, Railroad Equipment	-0.178	(-0.38)	-0.143	(-0.30)	-0.493	(-1.25)
Shipping Containers	-0.682**	(-2.45)	-0.880**	(-2.28)	-0.456	(-1.55)
Steel Works	-0.342*	(-1.86)	-0.433**	(-2.22)	-0.546**	(-2.63)
Textiles	-0.347	(-1.53)	-0.443*	(-1.71)	-0.330	(-1.17)
Tobacco Products	-0.411**	(-2.22)	-0.427	(-1.48)	-0.717***	(-2.93)
Transportation	-0.808**	(-2.58)	-1.742***	(-3.09)	-0.944***	(-2.85)
Wholesale	-0.434***	(-3.28)	-0.707***	(-3.36)	-0.293	(-1.52)
Number (%) of declines	**42**	**(95.5%)**	**44**	**(100.0%)**	**42**	**(95.5%)**
Number (%) of significant declines	**31**	**(70.5%)**	**37**	**(84.1%)**	**31**	**(70.5%)**