Why Did the Investment-Cash Flow Sensitivity Decline over Time?

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This version: November 2016

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Disclosure Statement

I declare that I do not have any potential conflicts of interest to disclose, as identified in the JF Disclosure Policy.

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I declare that I do not have any potential conflicts of interest to disclose, as identified in the JF Disclosure Policy.

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Abstract

We propose an explanation for why corporate investment used to be sensitive to cash flow and why the sensitivity declined over time. The sensitivity results from the importance of tangible capital and its productivity in the old economy. New-economy firms tend to operate with a higher level of intangible capital, face more intensive competition, and have cash flows which have less predictive power for their future values. As the number of new-economy firms grew and old-economy firms adapted to the new-economy environment, the average investment-cash flow sensitivity declined. The empirical results support our explanation of the sensitivity.

Key words: Investment-cash flow sensitivity, tangible capital, cash flow predictability, productivity, Q-theory, financial constraint

1. Introduction

The mainstream economic theory of corporate investment under perfect market assumptions, popularly known as the Q-theory, postulates that investment is determined by the marginal productivity of capital (Tobin 1969). In empirical work, the marginal Q is unobservable and the average Q is unable to explain the observed corporate investment activities. Instead, investment is found to be related to the cash flow firms generate in the same year (Fazzari, Hubbard and Petersen 1988). The investment-cash flow sensitivity is initially proposed as indicative of the existence of financial constraints, a form of market imperfection, as financially constrained firms must rely on their cash flow for new investment. An alternative explanation is that cash flow variation explains investment variation because current cash flow predicts future cash flow and investment is made in pursuit of future cash flow, consistent with the Q theory in general (Poterba 1988, Erickson and Whited 2000, and Alti 2003). An interesting phenomenon is that, while the debate is ongoing, the investment-cash flow sensitivity documented in the literature in the late 1980s had declined over time and by the new millennium it had almost disappeared (Allayannis and Mozumdar 2004, Brown and Petersen 2009, and Chen and Chen 2012). This declining pattern of investment-cash flow sensitivity has been puzzling financial economists.

In this paper, we propose an explanation for why the investment-cash flow sensitivity existed and why it declined. The explanation extends the notion that current cash flow explains investment because it predicts future cash flow to incorporate the role of the productive capital structure, which refers to a mix of two types of corporate productive capital—tangible capital and intangible capital. The intuition of the paper is straightforward: The investment-cash flow sensitivity documented in the literature is the sensitivity of tangible capital investment to current cash flow. Firms make optimal decisions on the amount of tangible and intangible capital investments to maximize their firm value. The investment and the resultant productive capital structure should reflect the relative productivity (profitability) of tangible capital and intangible capital. In the old economy, production relied more heavily on tangible capital, which leads to a high ratio of tangible capital in the productive capital structure. The current cash flow generated from the productive capital structure was informative about future productivity of the existing tangible capital. The (physical) investment-cash flow sensitivity existed because the current cash flow predicted future ones.

Over the last fifty years or so, the US economy has experienced large technological transformations from one that consisted more of traditional industries to one that embraces more of high-tech-oriented industries. These transformations were accompanied by an increase in the variety of industrial products, more complicated production processes, and more competitive environments for the firms. On one hand, the production processes nowadays rely more on intangible capital, especially for new firms in new industries. On the other hand, cash flow has become riskier and less predictable due to fast-changing consumer preferences and heavy competition among firms. As current cash flow now contains less information about future cash flow than it did in the past, investment has become less dependent on current cash flow, especially for physical investment. As a result, the investment-cash flow sensitivity declined over time.

Four sets of empirical results confirm the simple intuition outlined above. The first set of results comes from basic descriptive statistics of firm characteristics. During the sample period from 1972 to 2011, the number of manufacturing firms listed on the major US exchanges fluctuated mostly because of changes in the NASDAQ-listed firms. The average market-to-book asset ratio increased as more growth firms enter the sample. The average physical investment as a fraction of total assets declined by half over the sample period. The average cash flow as a percentage of total assets declined even more, while its volatility increased, mostly due to the newly listed high-tech firms. The average tangible capital as a percentage of total assets steadily declined, while that of intangible capital increased dramatically. This change in the productive capital structure reflects a change in the relative productivity of the two types of capital for the US firms over the sample period.

The second set of results represents the main results of the paper. We find that the investment-cash flow sensitivity is an increasing function of tangible capital, scaled by total assets. More importantly, the investment-cash flow sensitivity disappears once the cross-product term of cash flow and tangible capital is controlled for. The physical investment does not positively depends on cash flow for firms with low tangible capital. Only firms with high tangible capital have positive investment-cash flow sensitivity. Over time, however, the sensitivity of investment to the combination of cash flow and tangible capital declines. As a result, the investment-cash flow sensitivity also declines. We verify that, among many variables that can potentially explain the investment-cash flow sensitivity, tangible capital is the only one that does so satisfactorily. In particular, we show that the power of tangible capital in explaining the investment-cash flow sensitivity remains strong after controlling for many factors that proxy for financial constraints, indicating that the explanatory power of tangible capital is unlikely to be caused by financial constraints.

The third set of results show that the average autocorrelation of cash flow declined over time, which has been documented in the literature, and that the volatility of unpredicted future cash flow increased over time, suggesting that the investment-cash flow sensitivity in the early years was due to the predictive power of current cash flow for future cash flow and that the declining autocorrelation of cash flow was responsible for the declining investment-cash flow sensitivity. The increased cash flow volatility tends to be negatively associated with tangible capital and positively associated with intangible capital. The results provide a clue as to why the predictive power of current cash flow for future cash flow declined.

The fourth set of results reveal the roles tangible capital and intangible capital play in the productive process and how these roles change over time. Basic static economic models without adjustment costs imply that the share of a type of capital being used in production positively depends on its productivity. We estimate the average productivity of both tangible and intangible capital in a simple model with the Cobb-Douglas type of production function and show that the average productivity of tangible capital declined over time, while that of the intangible capital rose in the meantime. These findings explain why the share of tangible capital in total productive capital declined and why the sensitivity of investment to cash flow through tangible capital also declined.

We also use six criteria to divide firms into non-exhaustive groups to provide further evidence on our hypotheses. First, we divide firms into groups with high and low tangible capital ratio. Second, we divide firms into groups with strong and weak cash flow predictability. Third, we divide firms into groups with relative high tangible and intangible capital productivity. In each of these classifications, we find that the former group exhibits a much higher investment-cash flow sensitivity and a much stronger positive effect of tangible capital on this sensitivity than the latter group. These results indicate that the role of tangible capital in explaining investment-cash flow sensitivity is closely related to the cash flow predictability and the productivity of the two types of capital, consistent with our argument. The fourth way of classification pertains to the interpretation of the role played by tangible capital. Since tangible capital can be pledged as collateral for issuing debt, a potential explanation for its effect on the investment-cash flow sensitivity can be given from the financial constraint perspective (Almeida and Campello 2007). We analyze the role of tangible capital for financially constrained and unconstrained firms separately to provide evidence that the explanation from the productivity perspective is more convincing. In the fifth way of classification, we divide firms into old- and new-economy firms. We show that old-economy firms have greater investment-cash flow sensitivity than new-economy firms, that old-economy firms still have modest sensitivity even in later years, that old-economy firms rely more on tangible capital than new-economy firms, and that an average firm in the sample has declining tangible capital productivity and rising intangible capital productivity, again consistent with our hypotheses. Finally, we examine two balanced panels of firms, which have been used in the literature to argue that a changing firm composition in the data sample does not resolve the puzzle of declining investment-cash flow sensitivity (Chen and Chen 2012), as these balanced-panel firms also experienced declining sensitivity. We show that these firms actually have evolved over time in terms of their productive capital structure. In this sense, the changing firm composition in the data sample does play a crucial role.

The intended contribution of this paper is to shed light on the puzzle related to the investment-cash flow sensitivity. The issue of why investment is sensitive to cash flow has been debated in the literature for over two decades and the disappearance of the sensitivity has been confounding financial economists. We contribute by finding a variable, tangible capital, which completely explains away the investment-cash flow sensitivity and its declining trend. None of the studies in the literature has been able to achieve this. Although we find some evidence in line with the financial constraint explanation, our empirical results based on productive capital structure strongly support the explanation that the sensitivity is a result of cash flow predictability.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature on the investment-cash flow sensitivity. In Section 3 we propose our hypotheses for why the sensitivity declined and what implications the hypotheses have. We also briefly describe our empirical models and estimation methods. Section 4 explains the data and sample selection, reports descriptive statistics, and describes related background information. Section 5 presents the empirical results and Section 6 concludes.

2. Literature Review

2.1. Investment-Cash Flow Sensitivity

The neoclassical microeconomic theory derives corporate investment as the solution to a value maximization problem faced by firms whose production function exhibits constant returns to scale and adjustment costs. A related theory put forward by Tobin (1969) states that firm's investment rate is a function of Q, the ratio of the market value of (an additional unit of) capital to its replacement cost. Hayashi (1982) unifies the two theories. The Modigliani-Miller theorem under the perfect market assumption implies that corporate investment decisions are independent of financing decisions, such as those on internal liquidity, capital structure, and dividend policy. Myers and Majluf (1984) and Stiglitz and Weiss (1981), however, postulate that internal funds are much less costly than external funds because of asymmetric information between firm managers and outside investors. The empirical evidence on their implications is mixed.

In an influential paper, Fazzari, Hubbard, and Petersen (1988) argue that financing constraints affect corporate investment. Let INV and CF be the scaled investment and cash flow during a period, respectively, and MB be the market-to-book asset ratio, a measure of average Q. By dividing firms into three classes based on the dividend payout ratio, they find that the investment-cash flow sensitivity, a_2 in the regression[1]

$$\mathrm{INV}_{it} = a_0 + a_1 \mathrm{MB}_{i,t-1} + a_2 \mathrm{CF}_{it} + \varepsilon_{it}, \tag{1}$$

is higher for low dividend firms than for high dividend firms, while a_1 is economically insignificant. In their analysis, low dividend payout is a proxy for financing constraints. As such, the investment-cash flow sensitivity, a_2, in the regression model measures the degree of financial constraints and corporate investment is affected by financing constraints for financially constrained firms.

Kaplan and Zingales (1997) question the appropriateness of interpreting high investment-cash flow sensitivity as evidence that financial constraints affect investment. They build a simple model illustrating what is needed for financial constraints to have an effect on investment and how this is different from a simple regression like (1). In their empirical work, they extract from annual reports quantitative and qualitative information about whether the firms are financially constrained. On one hand, only a small fraction of the low dividend firms have reported financing difficulty. On the other hand, a large fraction of firms that are not financially constrained according to Kaplan and Zingales' classification exhibit a large a_2 in the investment-cash flow regression. Thus, whether a large a_2 is indicative of financial constraints is called into question. Later exchanges between the two groups of authors do not settle the debate. Cleary (1999) designs a sorting scheme for financial constraints based on firm characteristics and finds evidence supporting the findings of Kaplan and Zingales (1999). In Cleary's results, financially constrained firms have smaller investment-cash flow sensitivity.[2]

[1]Fazzari, Hubbard, and Petersen (1988) define Q as the sum of the value of equity and debt less the value of inventory, divided by the replacement cost of the capital stock, adjusted for corporate and personal tax considerations. In subsequent analyses in the literature, most researchers use the market-to-book asset ratio as the average Q.

[2]Grullon, Hund and Weston (2013) provide a granular analysis of the sensitivity and reached the same conclusion given by Kaplan and Zingales (1999) and Cleary (1999).

While the debate on whether investment-cash flow sensitivity measures financial constraints continues, researchers have turned to the question of why such sensitivity exists in the first place if not for financial constraints. The answer is also related to the question of why Tobin's Q fails to explain firms' investment behavior. Poterba (1988) suggests the possibility that cash flow may capture the marginal Q better than Tobin's Q.[3] Alti (2003) builds a neoclassical model without financial constraints to quantify the effect of cash flow on investment when Q is poorly measured. The calibration and simulation results show that investment is sensitive to cash flow and the sensitivity is higher for younger, smaller, higher growth, and lower dividend payout firms. Tobin's Q is more poorly measured for these firms as it captures long-term growth rather than short-term growth, which has an effect on current investment. Gomes (2001) presents a model with similar conclusions. Moyen (2004) considers two models, one with financial constraints and the other without. In the data simulated from both models, the investment-cash flow sensitivity is observed. This means that both explanations are plausible and thus the debate between the two schools remains unresolved.[4]

2.2. Time-series Trend of the Investment-Cash Flow Sensitivity

While the debate about the correct interpretation of the investment-cash flow sensitivity continues, an interesting development is that this sensitivity declined over time dramatically. While in the 1960s, the sensitivity coefficient a_2 stayed at around 0.4, by the 2000s it had dropped to near zero. Allayannis and Mozumdar (2004) document a sensitivity decline over the 1977-1996 period. They found that the decline is more obvious for financially constrained firms. Investment is not sensitive to cash flow when cash flow is negative. Agca and Mozumdar (2008) examine the sensitivity decline in relation to the reduction in market imperfection and claim that the decline is associated with increasing aggregate institutional fund flows, institutional ownership, analyst

[3] There is a large literature on the measurement errors in Tobin's Q, which could prevent Tobin's Q from explaining investment. See Erickson and Whited (2000) and the references therein.

[4] Almeida and Campello (2001) consider the credit constraints on the investment-cash flow sensitivity. Dasgupta, Noe and Wang (2011) examine the intertemporal effects of cash flow on the investment and non-investment uses of cash. Povel and Raith (2001) discuss the effect of asymmetric information. Dasgupta and Sengupta (2007) discuss the same issue in a multi-period framework. The latter two studies assume unobservability of investment and both find a non-monotonic relation between investment and cash flow.

following, anti-takeover amendments and with the existence of a bond rating. The contribution of the changes in these five capital market factors to the change in the investment-cash flow sensitivity is rather small, however. When the interactive terms of these factors with cash flow are added to the investment-cash flow regressions, the sensitivity measures reduce marginally and the goodness-of-fit measures increase only slightly. Brown and Petersen (2009) also question why the investment-cash flow sensitivity declined so sharply over time. They attribute it to the changing composition of investment from physical investment towards more R&D investment and the rising importance of public equity as a funding source. In their view, it is a combination of the decline in physical investment itself and the relaxing of financial constraints that causes the investment-cash flow sensitivity to decline. Chen and Chen (2012) note that the investment-cash flow sensitivity disappeared also during the 2007–2009 financial crisis when financial constraints were strongly binding. Therefore, the sensitivity cannot possibly be due to financial constraints. They report that the decline in the investment-cash flow sensitivity is very robust and cannot be reconciled by explanations proposed in previous studies. For example, the decline in the sensitivity occurs for small and large firms, young and old firms, firms with negative and positive cash flows, firms with and without credit ratings, firms with different corporate governance practices, and firms with different market power alike. The cash flow sensitivity declined over time for both physical investment and R&D investment. While measurement errors in Tobin's Q are ultimately the reason for the investment-cash flow sensitivity's existence in the first place, the reason for its decline remains, by and large, a mystery.

3. Hypotheses and Empirical Methodology

3.1. Hypotheses

The decline in the investment-cash flow sensitivity over time provides an opportunity for researchers to find out why it existed in the earlier years. Our hypotheses are based on the notion of productive capital structure. The productive capital structure refers to the mix of productive capital: tangible capital and intangible capital.[5] The main idea is that the product markets have evolved over time and, along with this, the production technologies have changed. More new products and services have emerged which rely more on innovative research and development. The productive capital structure has tilted more towards intangible capital, and the environment firms operate in has become more competitive. The predictability of future cash flow from the current cash flow in the later years is reduced. This causes the investment in tangible capital to be less traceable from the current cash flow.

The US economy in the past fifty years has experienced tremendous changes. Traditional industries declined in their importance, making way for new industries. In the early years of the sample period, old-economy firms dominated, producing more or less standardized products. Since the 1960s, new-economy firms have emerged, producing consumer electronics, medical equipment and health products, computers and software, mobile phones, etc. These new products were made possible through enormous efforts invested in research and development activities. As more new-economy firms got listed on exchanges, the overall productive capital structure changed. Tangible capital now plays a smaller role in production, while knowledge-based intangible capital has become more essential to economic growth. In fact, not only are new-economy firms conducting research and development, some of the old-economy firms are also developing newer products and changing their productive capital structure in order to gain market shares.[6]

Associated with new products and new technologies is the competition among firms. Whether a product or a firm can survive depends not only on the absolute quality and cost structure of its product, but also on its relative advantage to competitors. While this is also true for old-economy products and firms, it is more relevant to new-economy ones, as research and development involve higher degrees of uncertainty, products' life-span is much shorter, and consumers' tastes keep

[5]It is to be distinguished from the financial capital structure, which refers to the mix of various types of financial assets firms issue to raise funds: equity, debt, and their hybrid. The tangible capital is also to be distinguished from non-productive tangible assets such as inventories and cash holdings.

[6]A case in point is Nike, an athletic footwear and apparel maker, which officially belongs to a traditional industry, but has developed all kinds of high-tech gadgets related to sports and health, and is rightfully called a high-tech company in a Bloomberg Businessweek article by Brustein (2013).

changing. During the process of creative destruction, new-economy firms not only edge out old-economy firms, they also compete head-on among themselves in gaining market shares. As a result, many less successful firms, especially those smaller, newer ones, have a hard time making profits, even if their business plans are sound and their market valuations are high. This is reflected in the increased average cash flow volatility.

We hypothesize that the pattern in the time-series of the investment-cash flow sensitivity is a reflection of changes in cash flow predictability and the role productive capital structure plays. In the early years of our sample, the economy was dominated by old-economy firms, future cash flow can be predicted from current cash flow and the productive capital structure was heavily tilted towards tangible capital, as the output was mainly generated from the tangible capital. In the later years of the sample, however, the product market changed. Many new-economy firms that produced new products did not rely on tangible capital as much as the old-economy firms did. Even for some old-economy firms the productivity of tangible capital declined. As such, the physical investment rate declined, causing the share of tangible capital to drop. It should be noted, however, that not only has the composition of the firms been changing, the relative productivity of tangible and intangible capital and the productive capital structure of a given firm may also have been evolving over time.

In standard macroeconomics, a firm employs multiple productive factors, such as capital, labor, land, etc., to produce. The most popular type of production function is of the Cobb-Douglas type with constant returns to scale. For our purpose, let

$$Sales_{it} = A_{it} TC_{i,t-1}^{c_1} IC_{i,t-1}^{c_2}, \tag{2}$$

where $Sales_{it}$ is firm i's sales or total revenue, $TC_{i,t-1}$ is tangible capital, $IC_{i,t-1}$ is intangible capital, unscaled by firm size, and A_{it} captures the productivity shock and other productive factors. The proportional marginal products of tangible and intangible capital are captured by c_1 and c_2 respectively. Without adjustment costs, firms adopt the levels of tangible and intangible capital, which are positively related to their productivity, to maximize profits. While a dynamic model with adjustment costs is beyond the scope of this paper, it is not difficult to understand the logic behind an extended Q theory in which there are multiple productive factors, including both tangible capital and intangible capital, and the rate of investment (employment of additional productive factors) is determined by its marginal Q. As the marginal product of tangible capital relative to other productive factors varies across firms and over time, the physical investment rate and R&D investment rate will also vary. As a result, the productive capital structure contains information about the marginal products of various types of capital. As argued by other researchers, cited in the literature review, investment may vary with cash flow because cash flow can provide information about marginal Q. What we add to this argument is that the link between physical investment and cash flow also depends on tangible capital because it contains information about the marginal Q with respect to tangible capital.

While our hypotheses are intuitive, testing them is not an easy task. The difficulty lies in the unobservability of the productivity of tangible and intangible capital at a given point in time and at the firm level. This is deeply rooted in the difficulty of measuring marginal Q in general. In addition, intangible capital itself is difficult to measure. We proceed with our tests of the implications from our hypotheses with these difficulties in mind.

The implications from our hypotheses are stated in terms of the following regression equations. First, we extend the standard investment regressions as follows:

$$\mathrm{INV}_{it} = a_0 + a_1\mathrm{MB}_{i,t-1} + a_2\mathrm{CF}_{it} + a_3\mathrm{CF}_{it}\mathrm{TC}_{i,t-1} + a_4' x_{i,t-1}\mathrm{CF}_{it} + \varepsilon_{it}, \tag{3}$$

where $\mathrm{TC}_{i,t-1}$ is the tangible capital of firm i at the end of year $t-1$, scaled by its total assets, $x_{i,t}$ is a vector of other variables that can potentially provide alternative explanations for why the investment-cash flow sensitivity exists, and a_4 is the corresponding coefficient vector. The identity of x_{it} will be specified later. When the models are estimated over different subperiods, our hypotheses have certain implications for the parameters of the regression models. As documented in many studies cited in the literature review, when the model is estimated without interactive terms, a_2 declines over time. Under our hypotheses, when the model is estimated with the cross-product term $\mathrm{CF}_{it}\mathrm{TC}_{i,t-1}$, its coefficient a_3 should be positive and significant, while the significance of a_2 in early years should be weakened. In addition, if the hypotheses are true, the reason the investment-cash flow sensitivity, a_2 in (1), is reduced over time is that the sensitivity's reliance on tangible capital, a_3 in (3), is reduced over time.

Next, we will examine the autoregression model of cash flow

$$\mathrm{CF}_{it} = b_0 + b_1 \mathrm{CF}_{i,t-1} + \xi_{it}. \quad (4)$$

The autoregressive model has been used by Chen and Chen (2012) to argue that cash flow as a proxy for future profitability is most able to explain the investment-cash flow sensitivity. Besides the autoregressive coefficient b_1, the standard deviation of future cash flow which cannot be predicted from the current cash flow also indicates how informative current cash flow is about future cash flow. We examine how cash flow volatility depends on tangible and intangible capital by estimating the coefficients in the regression

$$|\xi_{it}| = e_0 + e_1 \mathrm{TC}_{i,t-1} + e_2 \mathrm{IC}_{i,t-1} + \xi^*_{it}. \quad (5)$$

Here, our hypothesis is that the risky nature of firms with high intangible capital has a positive effect on their cash flow volatility.

To trace the evolution over time of the average productivity of tangible and intangible capital, we consider the log version of (2) as follows:

$$\ln Sales_{it} \quad = \quad c_0 + c_1 \ln TC_{i,t-1} + c_2 \ln IC_{i,t-1} + \eta_{it}, \quad (6)$$

where $c_0 = E \ln A_{it}$ and $\eta_{it} = \ln A_{it} - c_0$. The parameters c_1 and c_2 measure the percentage increment of sales for a one-percent increase in tangible capital and intangible capital, respectively. Under our hypotheses, c_1 would decline, while c_2 would rise over time, indicating the declining productivity of tangible capital and rising productivity of intangible capital in the production process.

3.2. Empirical Methodology

The issues with the investment-cash flow sensitivity are typically analyzed in regressions of pooled observations on cross-sectional firms and over time. Our theme that the investment-cash flow sensitivity can be explained by tangible capital also involves both differences across firms and their changes over time. In order to show that the investment-cash flow sensitivity is not confounded with other firm-specific variables, the regressions are typically run with firm fixed effects. Following the literature, we estimate the investment, cash flow, and sales regressions with firm and year fixed effects. The regressions are estimated over ten-year subperiods and the coefficients for subperiods are reported to show the change. We implement firm fixed effects by subtracting the time-series mean from each variable in the entire sample period before running regressions.[7] To illustrate cross-sectional differences, we rely on subsamples that classify firms into different categories and report the results for each category. In all regressions, estimated parameters should be interpreted as average of the firm-specific parameters within the sample.

4. Data and Descriptive Statistics

4.1. Data, Variable Construction and Sample Selection

We construct our main sample based on the manufacturing firms (SIC codes from 2000 to 3999) in the COMPUSTAT annual file from 1972 to 2011. The starting point of the sample corresponds to the time when data on NASDAQ firms became available. Following Chen and Chen (2012) a firm is regarded as a high-tech firm if its three-digit SIC code is 283, 357, 366, 367, 382, or 384. We define the physical investment (INV) as the capital expenditure (COMPUSTAT item, CAPX) of a firm-year (i, t), scaled by the total assets (COMPUSTAT item, AT) at the beginning of the year. The cash flow (CF) for a firm-year (i, t) is the sum of the income before extraordinary item (COMPUSTAT item, IB) and the depreciation (COMPUSTAT item, DP) scaled by the beginning-of-the-year total assets. The market-to-book ratio (MB) of a firm is the ratio of the market value of total assets to the book value of total assets. The market value of total assets is the market capitalization (COMPUSTAT items, CSHO*PRCC_F), plus total assets, minus common equity (COMPUSTAT item, CEQ), minus deferred taxes (COMPUSTAT

[7] The adjusted R^2 with such a treatment would appear smaller than those in regressions with firm dummy variables.

item, TXDB). To make our results comparable to those in the literature, only firm-years that have relevant data to compute investment, cash flow and the market-to-book ratio are included in our sample. To be consistent with Chen and Chen (2012), we exclude firm-years for which we cannot calculate the lagged cash flow. Following Almeida, Campello and Weisbach (2004), we eliminate firm-years for which the sales growth or the asset growth exceeds 100 percent to avoid structural changes in the business of the firms. To ameliorate the effects from the outliers, for each firm-year we require that the net capital (net property, plant and equipment), book assets and sales in the previous year be equal to or greater than \$1 million. Furthermore, all variables, when used in the regressions, are winsorized at the one-percent level at both tails of the distribution for each year.

In our paper, tangible capital is the net property, plant and equipment (COMPUSTAT item, PPENT), scaled by the total assets at the beginning of the year. We aggregate three intangible capital variables to form the intangible capital used in the sales regressions. The Compustat Intangible Capital (CIC) is the intangible assets maintained by Compustat (COMPUSTAT item, INTAN). This item consists mostly of the excess of cost over assets acquired. Put differently, it measures how much a firm has paid for the assets of some target firms in excess of the book value of the assets of those target firms. In most of the cases an acquiring firm pays market-based extra for a target firm's brand name, copyrights, patents or other "intangible assets". The market-determined value in excess of book value reflects the asset's ability to generate profits in the future.

The second variable is the stock of R&D capital (RDC). We define this variable by capitalizing the annual expense in research and development activities using the perpetual inventory method. Specifically the R&D capital is calculated in accordance with the following equation:

$$RDC_{i,t} = (1 - \mu_{RD})RDC_{i,t-1} + RD_{i,t},$$

where $RD_{i,t}$ is the R&D expense (COMPUSTAT item, XRD) of firm i in year t and μ_{RD} is the depreciation rate used for R&D capital. Following Hall, Jaffe and Trajtenberg (2007) and Faloto, Kadyrzhanova and Sim (2013), we assume $\mu_{RD} = 15\%$.

The third variable is the stock of organizational capital. Eisfeldt and Papanicolaou (2013) define firm-level organizational capital in a way similar to the definition of R&D capital. Borrowing their method we calculate organizational capital (*OC*) by accumulating the selling, general and administrative expense over time as follows:

$$OC_{i,t} = (1 - \mu_{OC})OC_{i,t-1} + SG\&A_{i,t},$$

where $SG\&A_{i,t}$ stands for the selling, general and administrative expense (COMPUSTAT item, XSGA) of firm i in year t and μ_{OC} is the depreciation rate for organization capital, set to 25% as in Eisfeldt and Papanicolaou (2013).

Each of the measures defined above captures some aspect of intangible capital, but none of them is perfect. While *CIC* captures the intangible capital a firms has paid to acquire another firm, it does not capture the firm's own effort made in building its intangible capital. For firms that did not acquire other firms, this can be a serious issue. The main problem with *RDC* is that some newly listed, small firms do not bother to report their research and development and, as a result, their intangible capital is underestimated by *RDC*. Another obvious deficiency of *RDC* is that it only records the effort a firm has put into building its intangible capital without considering how effective that effort is. The same issue exists for *OC*. The perpetual inventory method, which uses a single constant rate over the entire sample period and across all firms to discount past expenses, is also subject to serious challenges.

We define intangible capital, *IC*, as the sum of the three variables, *CIC, RDC*, and *OC*, as each of these variables captures some aspect of the intangible capital which do not seem to overlap. In the sample we described earlier, less than 0.2% of firm-year observations end up having zero IC. These firms are deleted in order to facilitate the sales regressions.[8]

[8]In an earlier version, we maintained these firms and used 1+IC instead of IC in the sales regressions. The results are virtually the same.

4.2. Descriptive Statistics

During the sample period from 1972 to 2011, the number of manufacturing firms listed on the major US exchanges was fairly stable until 1991, increased towards 2000 and then declined after the so-called high-tech bubble. By 2011, the number of manufacturing firms was smaller than that at the beginning of the sample. Figure 1 plots the number of manufacturing firms that are classified as high-tech firms and the number of firms that are listed on the major exchanges. These plots show that, by and large, the number of manufacturing firms listed on NYSE and AMEX declined over time, while the number of manufacturing firms listed on NASDAQ increased until 1998 and slightly declined afterwards. The trends in the number of listed high-tech manufacturing firms are similar to the trends in the number of firms listed on NASDAQ.

Figure 1 here

Table 1 reports the descriptive statistics of the key variables used in this paper. Panel A lists the panel means. The average physical investments as a fraction of total assets, INV, declined from roughly 8% at the beginning of the sample period to roughly 4% by the end of the sample period. The market-to-book asset ratio, MB, is higher in the later years of the sample than in the earlier years, indicating that more growth firms are present in the sample in the later years. The average cash flows as a fraction of total assets, CF, sharply declined from more than 11% to just 2%. In the meantime, the average tangible capital as a fraction of total assets also declined from 32% to 22%. On the other hand, the means of all three intangible capital variables increased over time. The magnitudes of total assets-scaled CIC and RDC were small to begin with but increased quickly, while that of OC was large but increased modestly. As a result, IC, which is the sum of CIC, OC and RDC, is dominated by OC, but its change over time is attributed mainly to CIC and RDC. As explained before, the magnitudes of these intangible capital measures are subject to scrutiny. However, the pattern of the changes over time, especially compared with that of TC, provides valuable hints on what has changed in the productive capital structure.

The panel standard deviations of the key variables in Panel B provide further descriptions. While the mean of cash flow declined, the standard deviation increased. Accompanying the increased cash flow variations are the increased variations in the three intangible capital measures, hinting that the increased cash flow variations may have something to do with the increased, but diverse, intangible capital.

Table 1 here

Table 1 also reports the means and standard deviations of several variables that are potentially useful in explaining the investment-cash flow sensitivity. The WW index is constructed according to Whited and Wu (2006) to capture the degree to which a firm is financially constrained. The WW index is based on a GMM estimation of the investment Euler equation to measure firm-level financial constraints. It is a linear combination of six variables: cash flow, dividend dummy, firm size, leverage, firm sales growth and industry sales growth. Leverage (LV) is the book value of debt divided by the book value of total assets. While leverage is included in the WW index, it has a special role to play and deserves our attention. Cash holding (CH) is the amount of cash equivalent a firm has at the beginning of the year, scaled by total assets. Working capital (WC) is also scaled by total assets. Firm size (SZ) is the log of total assets. Cash flow volatility (CV) for a firm-year is the standard deviation of scaled cash flow, CF, during the previous five years.[9] The relevance of these variables will be explained later when they are used in the investment regressions. We note here that some of the variables do have time trends in their mean and standard deviation, which can be important for explaining the declining pattern in the investment-cash flow sensitivity.

5. Empirical Results

In this section, we present the empirical results. The investment regressions describe the role tangible capital plays in explaining the investment-cash flow sensitivity. The cash flow regressions

[9] By construction, WW=-0.091* cashflow - 0.062*dividend dummy + 0.021*leverage - 0.044*size + 0.102*industrial sales growth - 0.035*firm sales growth.

and sales regressions add supportive evidence to the hypotheses that the sensitivity came from the predictive power of current cash flow for future cash flow and that the investment-cash flow sensitivity declined because the productivity of tangible capital declined.

5.1. The Role of Tangible Capital in Investment Regressions

We examine the investment regressions (1) first and report the results in Panel A of Table 2. The slope coefficients, a_1, of the market-to-book ratio, $\mathrm{MB}_{i,t-1}$, are statistically significant throughout the entire sample period. They are economically insignificant, however, having values close to 0.01, whereas the theoretical value is one under the simplest model with a constant return-to-scale production function and without adjustment cost in Q-theory. Since a large literature exists on the measurement errors of Q and it is not the focus of the current paper, we will not discuss the coefficient of the market-to-book ratio in the remainder of the paper, but we keep $\mathrm{MB}_{i,t-1}$ in all the investment regressions as a control variable. The slope coefficient, a_2, of cash flow is significantly positive in each of the ten-year subperiods, but the magnitude steadily declines. Both the t-ratio and R^2 are substantially reduced in the later subperiods. The high investment-cash flow sensitivity in the early periods and its decline over time are the main features to be explained in this paper.

Table 2 here

In Panel B of Table 2 for regression model (3) with the added cross-product term of beginning-of-period tangible capital and cash flow, we find three very important results. First, the slope coefficient, a_3, of the cross-product term itself is significantly positive in each of the subperiods. This result implies that the well-documented positive investment-cash flow sensitivity is a function of tangible capital. Firms with higher tangible capital tend to invest more heavily when they have stronger cash flow, displaying a higher investment-cash flow sensitivity. Second, the slope coefficient of the linear term of cash flow, a_2, is insignificant for all subperiods except for the first one, after controlling for the cross-product term. Since the regressions are run with demeaned variables, this means that roughly half of the firms with low tangible capital tend not to exhibit positive investment-cash flow sensitivity, except for the first ten-year subperiod. In other words, the investment-cash flow sensitivity is mainly associated with firms having a high tangible capital.

The third result is that the slope coefficient, a_3, of the cross-product term of tangible capital and cash flow shows a pattern of decline over time. This pattern clearly demonstrates that the declining trend in the investment-cash flow sensitivity documented by Brown and Petersen (2009) and Chen and Chen (2012) is the outcome of a combination of two phenomena. One is declining (scaled) tangible capital. Since (3) simply extends (1) by claiming that the investment-cash flow sensitivity is a linear function of tangible capital, $a_2 + a_3\ \mathrm{TC}_{i,t-1}$, even if a_3 does not change over time, as $\mathrm{TC}_{i,t-1}$ declines over time (as shown in Table 1) the sensitivity would decline. The other phenomenon is a declining a_3 itself, as indicated in Panel B. We will further explain why the effect of tangible capital declines for a given level of tangible capital by looking at how cash flow predictability and tangible capital productivity have changed over time in a subsection below. The combination of a declining tangible capital and its declining effect on the investment-cash flow sensitivity causes the sensitivity to also decline over time.

Since tangible capital explains the investment-cash flow sensitivity, one wonders whether it explains investment itself. We digress from the sensitivity issue and look into this. Panel C of Table 2 presents the results of regressing INV_{it} on $\mathrm{TC}_{i,t-1}$, as well as on $\mathrm{MB}_{i,t-1}$ and $\mathrm{CF}_{i,t}$. It shows that variations in tangible capital do have some explanatory power for physical investment with a two-way causality: firms with high tangible capital productivity will invest more in tangible capital; large physical investment will also result in a large tangible capital. Note that $\mathrm{TC}_{i,t-1}$ is virtually uncorrelated with $\mathrm{MB}_{i,t-1}$ and CF_{it} in the panel. The explanatory power of $\mathrm{MB}_{i,t-1}$ and CF_{it} for investment is basically unchanged when $\mathrm{TC}_{i,t-1}$ is added in the regression.

So how much does the explanatory power of $\mathrm{TC}_{i,t-1}$ for INV_{it} contribute to explaining the investment-cash flow sensitivity? Panel D of Table 2 reports the regression with both linear and cross-product terms of CF_{it} and $\mathrm{TC}_{i,t-1}$. It shows that the linear term of $\mathrm{TC}_{i,t-1}$ does not affect, nor is it affected by, the cross-product term, CF*TC. The reason $TC_{i,t-1}$ explains the investment-cash flow sensitivity is not because it explains investment itself. Since we are interested in explaining the sensitivity, we will not involve the linear term of $TC_{i,t-1}$ in the investment regression in the rest of the paper.

In order to see how robust the total assets-scaled tangible capital is in explaining the investment-cash flow sensitivity, we use the tangible capital ratio, which is tangible capital scaled by the sum of tangible capital and intangible capital. Instead of repeating the same analysis in the full sample with total assets-scaled $TC_{i,t-1}$ replaced by the tangible capital ratio, we examine the same regressions for firms with high and low tangible capital ratios separately. Each year, firms in the top 30th percentile are regarded as high tangible capital ratio firms, while firms in the bottom 30th percentile are regarded as low tangible capital ratio firms. We then estimate the investment regressions for the high and low tangible capital ratio firms separately in the four ten-year subperiods. The average number of firms used in the regressions may differ for high and low tangible capital ratio firms because of data availability. Panels A and B of Table 3 report the mean and standard deviation of the relevant variables.

Table 3 here

From Panels A and B, it can be seen that low tangible capital ratio firms tend to make smaller physical investment than high tangible capital ratio firms. This is why they end up being low tangible capital ratio firms. They tend to be growth firms in the sense of high market-to-book ratio, but their cash flow is low on average and more volatile. As expected, low tangible capital ratio firms also have low TC and high IC, which are scaled by total assets. Both groups of firms display a decreasing trend in tangible capital and an increasing trend in intangible capital over time, but the trend is more obvious for low tangible capital ratio firms.

Panel C of Table 3 shows the investment regression for the high and low tangible capital ratio firms separately. It is clear that high tangible capital ratio firms tend to have larger investment-cash flow sensitivity than low tangible capital ratio firms. The coefficients for high tangible capital ratio firms are more than double those for low tangible capital ratio firms. The investment-cash flow sensitivity declines over time for both types of firms, but even in the later years, high tangible capital ratio firms continue to have much higher sensitivity than low tangible capital ratio firms.

5.2. Alternative Explanations with Other Variables

Studies in the literature have documented that the many firm characteristics have evolved over the decades in addition to tangible capital. These characteristics may affect both the capital investments and the investment-cash flow sensitivity. Our parsimonious specifications above do not include these firm characteristics. We examine these characteristics here and see whether our previous results are robust to the addition of these variables and whether they can provide alternative interpretations.

Since the ongoing debate concerns whether the existence of the sensitivity indicates financial constraints, we consider a few variables that represent financial constraints. The most popular one is firm size because it is the most visible indicator of a firm's credibility in the financial market. It has been shown in the literature that the WW index also captures many aspects of financial constraints. A higher value of the WW index means that the firm has more financial constraints. If the investment-cash flow sensitivity arises from financial constraints, the cross-product term of the WW index and cash flow should carry a positive coefficient.

Leverage reflects the reliance of a firm's financing on debt. Leverage is positively related to financial constraints in the WW index. High leverage firms have difficulty in raising further funds. Given their assets, high leverage firms pay more interest out of cash flow, so their investment relies more on cash flow. Therefore, if financial constraints are the main driver of the investment-cash flow sensitivity, the cross-product term of $\mathrm{LR}_{i,t-1}$ and CF_{it} should have a positive coefficient. On the other hand, high leverage firms face the debt-overhang problem which may adversely affect investment, although its effect on the investment-cash flow sensitivity is unclear. In addition, leverage serves as a control variable for examining the effect of other variables.

Bates, Kahle and Stulz (2009) find that the average cash holdings (cash-to-assets ratio) of

U.S. firms have more than doubled from 1980 to 2006, a pattern also seen in Table 1 over our sample period. If the investments of financially constrained firms truly rely on internal cash flows, a higher level of cash holdings as internal funds would definitely reduce the reliance of investment on cash flow, and hence reduce the investment-cash flow sensitivity.

Bates, Kahle and Stulz (2009) also regard working capital as a liquid asset, and a substitute for cash holdings. Therefore if financial constraints matter for investment, working capital should have a negative effect on the investment-cash flow sensitivity. Working capital declined on average, however, over the sample period.

Besides variables associated with the financial constraint explanation, we also look at a variable associated with the Q theory explanation. A large number of papers have been devoted to studying how firm-level cash flow volatility affects corporate investments. Minton and Schand (1999) find that firms with a higher level of cash-flow volatility are associated with a lower level of capital investment. They argue that firms with more volatile cash flows are more likely to experience funding shortfalls, in which case they tend to forgo investment projects. In our sample the mean of firm-level cash-flow volatility more than doubled from 1972 to 2011, which might also cause both the capital investment and the investment-cash flow sensitivity to decline. Wang, Xiao and Zhang (2014) find evidence that the rising volatility of firm fundamentals contributes to the decline in investment-cash flow sensitivity.[10]

We test how the firm characteristics, WW index (WW), leverage (LR), cash holding (CH), working capital (WC), firm size (SZ) and cash flow volatility (CV), affect the investment-cash flow sensitivity, individually and collectively, in comparison with tangible capital. Panel A of Table 4 reports the results of the investment regressions using these variables collectively without TC. The results can be summarized as follows. (A) From the sign of the WW*CF coefficient, more financially constrained firms tend to have lower investment-cash flow sensitivity, inconsistent with the financial constraint explanation. (B) From the sign of the LR*CF coefficient, firms with higher leverage tend to have lower sensitivity, also inconsistent with the financial constraint

[10] We use cash flow volatility mainly for control purpose, as cash flow volatility may also have implications for financial constraints.

explanation.[11] (C) From the sign of the CH*CF coefficient, firms with greater cash holding tend to exhibit lower sensitivity, consistent with the financial constraint explanation. (D) From the sign and significance of the WC*CF coefficient, firms with more working capital tend to exhibit lower sensitivity in the first two ten-year subperiods, consistent with the financial constraint explanation, but the effect disappears later. (E) From the sign of the SZ*CF coefficient, large firms in the first and last subperiods tend to have lower sensitivity, but the effect is not stable. (F) From the sign of the CV*CF coefficient, firms with more volatile cash flow tend to have smaller sensitivity, consistent with the Q theory. (G) Most importantly, these additional variables do not change the sign and significance of cash flow itself. They may contribute to affecting the sensitivity, with signs in the wrong direction in some cases, but they are far from being able to fully explain why the sensitivity existed and why it declined.

Table 4 here

Panel B of Table 4 reports the investment regression in which the cross-product term of cash flow and tangible capital is added together with the other cross-product terms. Three results stand out. First, the coefficient of the cross-product term with tangible capital remains significantly positive in all subperiods. Second, the coefficients of cash flow itself become statistically insignificant, as we have seen in Table 2. Third, some variables that appear to be consistent with one of the explanations in the regression without TC*CF either lose their explanatory power completely. These results clearly show that tangible capital is the only variable among those being considered that can explain the investment-cash flow sensitivity and its decline over time.

5.3. Tangible Capital and Financial Constraints

Since the financial constraint theory is a mainstream explanation of the investment-cash flow sensitivity, we perform further tests on financially unconstrained and constrained firms separately.

[11] If the linear term LR is included in the regression, its coefficient is significantly negative, consistent with the debt-overhang prediction. The coefficient of LR*CF remains negative, albeit less significant, so the effect predicted by the financial constraint explanation of the investment-cash flow sensitivity is absent.

We adopt the WW index to define financially constrained and unconstrained firms. In each year firms in the top (bottom) three deciles are defined as financially constrained (unconstrained). We then run investment regressions for firms in the two categories separately. The results are reported in Table 5 along with the descriptive statistics.[12]

Table 5 here

The numbers in Panels A and B show that constrained firms tend to have a slightly lower investment rate, a higher market-to-book ratio, and a lower level of tangible capital. However, constrained firms have much lower cash flow, higher cash flow volatility and higher intangible capital. These are features that make these firms financially constrained. The results in Panel C show that the investment-cash flow sensitivity, a_2, is lower for constrained firms than unconstrained ones, consistent with the results in Table 4 that the coefficient of the cross-product term of WW and CF is negative. This result once again confirms those reported by Kaplan and Zingales (1997) and Cleary (1999) with different measures of financial constraints.

One result in Panel C in particular sheds new light on the existing results in the literature. Here we examine the role of tangible capital in explaining the investment-cash flow sensitivity across financially unconstrained and constrained firms. Almeidan and Campello (2007) use some version of tangible capital and find a similar result that tangible capital positively explains the investment-cash flow sensitivity, but only for financially constrained firms. They interpret this as evidence supporting the financial constraint explanation for the investment-cash flow sensitivity.[13] Our result in Panel C shows that for both constrained and unconstrained firms tangible capital explains the investment-cash flow sensitivity. In fact, the effect is larger for financially unconstrained firms. This is consistent with the notion that tangible capital is positively related to the predictability of cash flow. A high level of tangible capital indicates a more predictable

[12]In an earlier draft, we also reported results from classifications based on dividend dummy, firm size, bond rating, etc. All the results are consistent with those using the WW index and thus are not reported here.

[13]Their interpretation is based on the credit multiplier channel. For financially constrained firms, physical investment out of cash flow increases tangible capital which can be pledged as collateral to ease financial constraints and to make further investment. Financially unconstrained firms do not rely on cash flow to make investment, and therefore there is no such effect.

cash flow. Firms tend to have higher investment-cash flow sensitivity if they have more tangible capital. This effect of tangible capital is stronger for unconstrained firms simply because they are more capable of raising funds for future investment opportunities.

Since we find seemingly opposite results to those in Almeidan and Campello (2007) for unconstrained firms, it is necessary to reconcile these two sets of empirical findings. The main difference in the empirical implementations between the two studies is the definition of firm-level asset tangibility. The measure of asset tangibility in Almeida and Campello (2007) is a linear combination of receivables, inventory and fixed assets. All three components in this definition are pledgeable assets. Asset tangibility is constructed to measure the expected asset liquidation value that creditors are able to capture in case of bankruptcy, which in turn determines the amount of money creditors are willing to lend. It is clear that this definition focuses more on the pledgeability of the assets. However, tangible capital in our study is defined as productive capital scaled by total assets. Receivables and inventories are not included, as they do not contribute to productivity. Besides, Almeida and Campello (2007) scale the capital expenditure and cash flow using beginning-of-period fixed assets, while we scale all variables using the beginning-of-period book value of total assets, as we are interested in how the productivity of different types of capital affects the investment-cash flow sensitivity.

The results we present here do not nullify the pledgeability of tangible capital in explaining the investment-cash flow sensitivity, but we can see that the pledgeability of tangible capital is not driving our results.[14] The productivity channel of tangible capital dominates the credit multiplier channel in explaining the investment-cash flow sensitivity. In addition, the explanation based on the credit multiplier channel is mostly silent on the declining sensitivity.

5.4. Cash Flow and Sales Regressions

If the investment-cash flow sensitivity reflects the predictive power of current cash flow for future cash flow and a declining sensitivity reflects a declining predictive power, it should be obvious

[14]As Table 4 shows, the effect of tangible capital on the investment-cash flow sensitivity does not change when leverage (LR) is controlled for. The credit multiplier channel would work only if leverage increases.

from the cash flow autoregressions. Panel A of Table 6 reports the cash flow autoregressions for the subperiods for the full sample. It shows that the autoregressive coefficient, represented by b_1, is indeed strongly significant in all subperiods, but declining over time. Chen and Chen (2012) illustrate the declining pattern of b_1 graphically. The result reported here is consistent with theirs. Besides the autocorrelation coefficient, another measure that conveys the same message is the residual variance, σ_ξ, reported for each regression for a subperiod. This is an aggregated version of CV used in the previous subsection. Over the four ten-year subperiods, the aggregate residual volatility has increased. This increased cash flow conditional volatility makes future cash flow increasingly less predictable, contributing to the declining investment-cash flow sensitivity.

Table 6 here

The estimated autoregressive coefficient of cash flow in a panel regression is basically the average of the autoregressive coefficients of cash flow for each firm, which may exhibit features related to various firm characteristics. Here we are interested in how this autoregressive coefficient depends on tangible capital. Panel B reports the regression results with an added cross product term, $\mathrm{CF}_{it}*\mathrm{TC}_{i,t-1}$, which captures the dependence of the autoregressive coefficient on tangible capital. It shows that this dependence is positive, although its contribution to goodness-of-fit is small.[15]

Panel C of Table 6 reports the results of regressing the absolute value of the error term from the autoregressive model of cash flow, $|\xi_{it}|$, on scaled tangible capital $\mathrm{TC}_{i,t-1}$ and intangible capital $\mathrm{IC}_{i,t-1}$. The magnitude of the error is found to be insignificantly related to $\mathrm{TC}_{i,t-1}$, but positively related to $\mathrm{IC}_{i,t-1}$.[16] The results indicate that as intangible capital of a typical firm increases over time, its cash flow risk also grows.

To gain further evidence on the role of cash flow predictability in explaining the investment-cash flow sensitivity, we again look at the subsamples divided by the predictability. Within

[15] We also run regressions of future three-year cash flow on current cash flow and the cross-product of current cash flow and tangible capital. The results are even stronger.

[16] The reason that $\mathrm{TC}_{i,t-1}$ is insignificant is partly because both TC and IC are scaled by total assets, which mainly consist of tangible assets. If TC and IC are replaced by a single variable, the tangible capital ratio defined as $\mathrm{TCR}_{i,t-1} \equiv \mathrm{TC}_{i,t-1}/(\mathrm{TC}_{i,t-1} + \mathrm{IC}_{i,t-1})$, then $|\xi_{it}|$ would be negatively and significantly related to $\mathrm{TCR}_{i,t-1}$.

each of the ten-year subperiod, firms with more predictable cash flow are defined as firms whose slope coefficient in the cash flow autoregression is in the top 30% and whose residual standard deviation is in the bottom 30%, while firms with less predictable cash flow are defined as firms whose slope coefficient of the cash flow autoregression is in the bottom 30% and whose residual standard deviation is in the top 30%. Panels A and B of Table 7 report the mean and standard deviation of the key variables for these two groups of firms separately. The descriptive statistics show that the investments of these two groups are about the same on average, although the variation is slightly greater with the group with less predictable cash flow. This group tends to be growth firms and accumulates more intangible capital. The most striking difference is that firms with less predictable cash flow have much lower cash flow on average and the variation among them is much greater.

Table 7 here

Panel C of the table reports the results of investment regressions for the two groups of firms. It confirms that the investment-cash flow sensitivity is much higher for the group with more predictable cash flow than for the group with less predictable cash flow. Even in the last ten-year subperiod, the sensitivity for the group with more predictable cash flow is high. On the contrary, the sensitivity for the group with less predictable cash flow is high only in the first ten-year subperiod. Furthermore, tangible capital has a significantly positive effect on the investment-cash flow sensitivity for firms with more predictable cash flows, but a generally insignificant effect for firms with less predictable cash flows. This is consistent with our argument that tangible capital explains the investment-cash flow sensitivity because it is closely related to the predictability of cash flow.

5.5. Productivity of Tangible and Intangible Capital

The extended Q-theory explanation of the investment-cash flow sensitivity in this paper is based on the productivity of tangible and intangible capital. In this section, we make an attempt to estimate the productivity to further examine the validity of the extended Q-theory explanation.

As we have explained before, estimating the productivity using data at the firm level is challenging, so the analysis should be viewed as simply exploratory. Panel A of Table 8 reports the sales regressions (2) for subperiods for the entire sample, treating the productivity as a economy-wide parameter. It shows that the productivity of tangible capital, represented by c_1, is strongly significant in all subperiods, but declining over time. The productivity of intangible capital, represented by c_2, is also significant in all subperiods and increasing over time. These patterns are consistent with our hypotheses.[17]

Table 8 here

The sales regression is also estimated at the firm level, with productivity treated as a 3-digit SIC industry-wide parameter. There are 127 such industries. Panel B of Table 8 reports the mean and standard deviations of the estimates across industries. The mean estimates of c_1 and c_2 are close to the economy-wide estimates. The standard deviations, however, are large, especially for the productivity of intangible capital.[18]

The results presented in Table 8 are broadly consistent with our hypotheses. As we have argued, the nature of U.S. firms has changed profoundly over time. They are now relying more on new technologies and face more fierce competition than before. As more intangible capital-intensive firms enter the sample, tangible capital plays a less essential role, so the firms invest relatively less in physical capital, causing the share of tangible capital to decline. Meanwhile, current cash flow has less predictive power for future profitability. Therefore the investment-cash flow sensitivity declines over time.

We form two non-exhaustive groups of firms. The firms with high TC productivity and low IC productivity are firms in industries whose c_1 is in the top 30% and whose c_2 is in the bottom

[17]There is evidence, however, that c_2 is underestimated. It has been well documented by Fama and French (2004), for example, that newly listed high-tech firms have left-skewed earnings. This is also true for sales. This causes a downward bias in the OLS estimate of c_2. We are more curious about the trend over time, rather than its absolute magnitude, however.

[18]Some estimates of c_2 are negative, which does not make sense from the ex ante perspective. On the other hand, the magnitude of the errors σ_η becomes smaller here, because the model is more flexible and allows parameters to vary across industries.

30%. The firms with low TC productivity and high IC productivity are firms in industries whose c_1 is in the bottom 30% and whose c_2 is in the top 30%. For each group, we report the descriptive statistics of the key variables and the results of the investment regressions in Table 9.

Table 9 here

The descriptive statistics reveals that the main difference between the two groups is their composition of tangible and intangible capital. The group with high tangible capital productivity and low intangible capital productivity has on average a higher level of tangible capital and a lower level of intangible capital. This makes sense as firms invest and accumulate capital in the area where productivity is high. The investment regression results in Panel C show that the investment-cash flow sensitivity is substantially higher for the group with high tangible capital productivity and low intangible capital productivity, consistent with the prediction from the extended Q-theory explanation. Even in the last ten-year subperiod, the investment-cash flow sensitivity is still significantly positive.[19] In addition, tangible capital has a much stronger positive effect on the investment-cash flow sensitivity for the firms with high TC productivity and low IC productivity. This is consistent with the notion that tangible capital is a proxy for the relative productivity of tangible and intangible capital. Therefore, it can explain the investment-cash flow sensitivity.

5.6. The Old-economy and New-economy Firms

In this subsection, we classify firms that are non-high-tech and listed on NYSE as old-economy firms and firms that are high-tech and listed on NASDAQ/AMEX as new-economy firms. The classification is non-exhaustive, as many firms are unclassified. This classification of new- and old-economy firms is a crude and oversimplified one. Nevertheless it may provide additional evidence

[19] We note that estimation errors in the sales regressions create noise in the classification of the two groups. But these potential errors will not create bias in favor of finding the results reported here. We also tried classifying firms into two groups by their tangible capital productivity only, irrespective of their intangible capital productivity. The corresponding results are very similar to those reported here.

to our hypotheses. Note that such a crude classification would not work to our advantage in making our point.

Panels A and B of Table 10 show the mean and standard deviation of the main variables for the old- and new-economy firms. The number of old-economy firms declines over time, while that of new-economy firms increases. The new-economy firms tend to have higher market-to-book ratios, as the cash flow of most of them is expected to grow. The competition, however, renders their sales and cash flow low. In the last two decades, the cash flow of the new-economy firms is in fact negative on average with a large standard deviation, while the cash flow of the old-economy firms remains high with a smaller standard deviation. The average tangible capital of the new-economy firms is lower than that of the old-economy firms, but the average intangible capital of the new-economy firms is higher than that of the old-economy firms. A closer look at the components of IC (not reported in the table) shows that the old-economy firms have higher Compustat intangible capital than the new-economy firms, as the old-economy firms tend to be larger firms and are more likely to be acquirers in mergers and acquisitions. The new-economy firms, however, spend much more on building R&D capital and organizational capital than the old-economy firms.

Table 10 here

The results of the investment regressions for the old- and new-economy firms are given in Panel C of Table 10. Both types of firms show similar patterns to those seen in Table 2. That is, the investment-cash flow sensitivity is significantly positive and declining over time when cash flow alone is used in the investment regression without tangible capital, but becomes insignificant when the cross-product term with tangible capital is added. What is new in this table is the difference between the old- and new-economy firms. First, the investment-cash flow sensitivity parameter, a_2, is much smaller for the new-economy firms than for the old-economy firms. This naturally implies that, as the new-economy firms increase while the old-economy firms decrease in number, the investment-cash flow sensitivity for the full sample declines over time. However, for some old-economy firms, the sensitivity is still quite high even in the last ten-year period of the sample. Second, while for both types of firms the slope coefficients of cash flow are insignificant after the cross-product term is added, the slope coefficient, a_3, of the cross-product term of cash flow and tangible capital is much smaller and less significant for the new-economy firms than for the old-economy firms in all subperiods. Third, for all regressions, the goodness-of-fit is greater for the old-economy firms than for the new-economy firms.

Panels D and E of Table 10 report the results of the cash-flow regressions and the sales regressions for old- and new-economy firms. For the cash-flow regressions, the autoregressive coefficients are much higher for the old-economy firms than for the new-economy firms. For the sales regressions, the productivity of tangible capital is higher for the old-economy firms than for the new-economy firms, while the productivity of intangible capital is higher for the new-economy firms than for the old-economy firms. There is a declining pattern in the productivity of tangible capital and a rising pattern in the productivity of intangible capital, although not monotonically.

Overall, the results for the old-economy firms and the new-economy firms in Table 10 provide further evidence supporting our hypothesis that the investment-cash flow sensitivity in the earlier years is mainly due to cash flow's predictive power for its own future value. The results also indicate that the declining investment-cash flow sensitivity is related to the increasing role of the new-economy firms which have less predictable future cash flow. The results show the importance of tangible capital in explaining the variation in corporate investment.

5.7. Balanced Panel Firms

This subsection deals with balanced-panel firms. Chen and Chen (2012) find that balanced panel firms also show a declining pattern in the investment-cash flow sensitivity over time. They doubt the decline in the sensitivity in the full sample can be attributed to the changing composition of firms in the sample, as the pattern of decline is also observed for the balanced panel of firms unchanged in the sample.

We construct two balanced-panel subsamples of firms. The first subsample consists of 207 manufacturing firms that operated during the 1972-1991 subperiod and the second subsample consists of 262 manufacturing firms that operated during the 1992-2011 subperiod. Very few (less than 60) manufacturing firms operated throughout the entire sample period of 1972-2011, so they are not examined. Panels A and B of Table 11 report the mean and standard deviation of the key variables for the two balanced-panel subsamples. While the set of firms remained the same, their characteristics changed over time. In the first balanced-panel subsample, the mean of tangible capital did not change much. In the second balanced-panel subsample, tangible capital reduced substantially over time. For both balanced-panel samples, intangible capital increased substantially. The mean of scaled sales and cash flow reduced over time for both sets of firms. While the volatility of sales reduced somewhat, the volatility of cash flow increased. Therefore, these balanced-panel firms should not be regarded as the same set of firms over time as their characteristics have changed.

Table 11 here

Panels C, D and E of Table 11 report the investment, cash flow, and sales regressions for the two balanced panels. For both panels, the investment-cash flow sensitivity a_2 declines over time when the cross-product term $\mathrm{CF}_{it}*\mathrm{TC}_{i,t-1}$ is absent. It becomes insignificant when the cross-product term is added. For the first panel, while TC does not decline, the coefficient of the cross-product term a_3 is large in early subperiods and declines over time. This explains why a_2 estimated without the cross-product term declines over time. For the second panel, while a_3 actually increases, tangible capital declines, and so a_2 in the equation without the product term also declines. Although the investment-cash flow sensitivity of the two balanced-panel subsamples declines for slightly different reasons, both are related to the changes in tangible capital. In Panel D, the results in cash flow regressions show that the firms in the first balanced panel exhibit a decline in cash flow persistence, while cash flow volatility reduces. For the second set of balanced-panel firms, neither the persistence nor the volatility changes much. The results in Panel E show that the balanced-panel firms also experienced similar changes in productivity to the unbalanced-panel firms as shown in Table 8. The productivity of tangible capital decreased, while the productivity of intangible capital increased.

Overall, the results on the balanced-panel firms indicate that, although they are the same firms by name, they are not the same firms from the economic perspective. Their productive capital structure has changed and so has their relative capital productivity. Their investment-cash flow sensitivity declined because they underwent similar changes to the average firms in the entire economy, albeit with a smaller magnitude.

6. Conclusions

We have proposed and examined hypotheses about why corporate investment is sensitive to cash flow and why the sensitivity has declined. The explanation is built on the existing explanation in the literature that current cash flow explains investment because it predicts future cash flow. We emphasize the role of tangible capital productivity in this explanation. In our framework, the economy has been changing from an old economy which relies more on tangible capital to a new economy which depends more on intangible capital. The new-economy firms, however, also face more competition and their future cash flow is less predictable from the current cash flow. As a result, current cash flow contains less information about future cash flow and investment becomes less responsive to current cash flow.

The main contribution of the paper is that we provide empirical results which confirm our explanation for why the investment-cash flow sensitivity exists and why it has declined over time. These questions have puzzled financial economists for decades. During the sample period, the number of manufacturing firms listed on the major US exchanges fluctuated mostly because of changes in the number of high-tech firms listed on NASDAQ. The average cash flow declined, caused by competition among the newly listed high-tech firms. The average fraction of tangible capital in total assets also declined, reflecting a change in the productive capital structure. More importantly, the tangible capital productivity declined over time and cash flow became less predictable. The new-economy firms had smaller investment-cash flow sensitivity than old-economy firms. It is the decline in tangible capital and tangible capital productivity in the economy that caused the investment-cash flow sensitivity to drop.

We also provide evidence that tangible capital explains investment but not because it can be used as collateral for reducing financial constraints. We find that the investment-tangible capital sensitivity is higher for non-constrained firms than constrained firms. We contribute to the literature by providing evidence favoring the cash-flow predictability explanation over the financial constraint explanation.

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Table 1
Descriptive statistics of key variables

This table presents the ten-year panel mean and standard deviation of the market-to-book ratio (MB), physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), Compustat intangible capital (CIC), organizational capital (OC), R&D capital (RDC), the composite intangible capital (IC), Whited-Wu index (WW), leverage (LR), cash holding (CH), working capital (WC), firm size (log of total assets, SZ), and cash flow volatility (CV). Except for SZ and MB, all variables are scaled by total assets. MB, TC, CIC, OC, RDC, and IC are measured at the beginning of the year. NF is the average number of firms.

A. Mean								
Period	INV	MB	CF	SA	TC	CIC	OC	RDC
1972-1981	0.08	1.15	0.11	1.71	0.32	0.02	1.10	0.06
1982-1991	0.07	1.41	0.07	1.43	0.31	0.03	1.31	0.13
1992-2001	0.06	1.90	0.05	1.30	0.28	0.07	1.39	0.23
2002-2011	0.04	1.92	0.02	1.09	0.22	0.15	1.42	0.33
	IC	WW	LR	CH	WC	SZ	CV	NF
1972-1981	1.19	-0.24	0.24	0.08	0.36	4.40	0.04	1599.6
1982-1991	1.47	-0.24	0.25	0.11	0.30	4.61	0.07	1575.0
1992-2001	1.69	-0.24	0.24	0.14	0.24	4.98	0.11	1755.7
2002-2011	1.90	-0.27	0.20	0.21	0.16	5.68	0.14	1458.3
B. Standard deviation								
Period	INV	MB	CF	SA	TC	CIC	OC	RDC
1972-1981	0.06	0.73	0.07	0.67	0.14	0.05	0.68	0.09
1982-1991	0.06	0.81	0.12	0.65	0.15	0.06	0.87	0.18
1992-2001	0.06	1.46	0.19	0.65	0.17	0.11	1.11	0.36
2002-2011	0.04	1.32	0.20	0.63	0.16	0.17	1.28	0.55
	IC	WW	LR	CH	WC	SZ	CV	NF
1972-1981	0.71	0.09	0.15	0.08	0.15	1.63	0.04	1599.6
1982-1991	0.93	0.11	0.18	0.13	0.16	1.88	0.08	1575.0
1992-2001	1.25	0.11	0.21	0.19	0.17	1.89	0.19	1755.7
2002-2011	1.51	0.12	0.22	0.22	0.16	2.00	0.28	1458.3

Table 2
Investment-cash flow sensitivity: the role of tangible capital

This table presents the ten-year panel regressions of investment on cash flow and its cross-product term with tangible capital for the full sample. INV, CF, TC are physical investment, cash flow, and tangible capital respectively, scaled by total assets. MB is the market-to-book ratio. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level. NF is the average number of firms. R^2 is the adjusted R^2 for serially demeaned panel data.

$$\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + a_4\text{TC}_{i,t-1} + \varepsilon_{it}$$

	Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	TC	t-stat	NF	R^2
A.	1972-1981	0.008	8.15	0.267	23.25					1599.6	0.13
	1982-1991	0.013	11.30	0.143	20.20					1575.0	0.11
	1992-2001	0.009	15.68	0.064	15.07					1755.7	0.09
	2002-2011	0.006	12.63	0.043	12.75					1458.3	0.07
B.	1972-1981	0.009	8.98	0.107	5.73	0.515	8.56			1599.6	0.14
	1982-1991	0.014	12.08	0.015	1.24	0.444	10.32			1575.0	0.12
	1992-2001	0.009	16.06	-0.002	-0.36	0.274	9.16			1755.7	0.11
	2002-2011	0.006	13.05	-0.005	-1.17	0.221	8.46			1458.3	0.10
C.	1972-1981	0.009	8.50	0.267	23.46			0.041	4.26	1599.6	0.13
	1982-1991	0.014	11.76	0.144	20.26			0.038	4.82	1575.0	0.11
	1992-2001	0.009	15.91	0.064	15.16			0.036	4.85	1755.7	0.10
	2002-2011	0.007	13.90	0.041	12.35			0.096	13.79	1458.3	0.12
D.	1972-1981	0.009	8.92	0.089	3.94	0.574	7.37	-0.017	-1.37	1599.6	0.14
	1982-1991	0.014	12.26	0.021	1.73	0.422	9.53	0.017	2.06	1575.0	0.13
	1992-2001	0.009	16.26	0.000	0.05	0.264	9.05	0.029	3.97	1755.7	0.11
	2002-2011	0.007	14.33	-0.003	-0.69	0.204	8.77	0.092	13.87	1458.3	0.14

Table 3
High tangible capital ratio firms vs low tangible capital ratio firms

For high tangible capital ratio firms and low tangible capital ratio firms, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment, cash flow, and sales regressions, respectively. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	High tangible capital firms							Low tangible capital firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.10	1.05	0.12	1.56	0.45	0.57	519.1	0.06	1.23	0.10	1.79	0.19	1.98	353.0
1982-1991	0.09	1.34	0.08	1.29	0.44	0.71	529.8	0.05	1.44	0.05	1.60	0.17	2.54	298.2
1992-2001	0.08	1.60	0.07	1.23	0.42	0.78	599.2	0.04	2.14	-0.03	1.35	0.12	3.12	316.0
2002-2011	0.05	1.61	0.07	1.16	0.36	0.95	537.4	0.02	2.30	-0.09	1.00	0.06	3.55	216.9

B. Standard deviation

	High tangible capital firms							Low tangible capital firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.07	0.55	0.07	0.67	0.13	0.27	519.1	0.05	0.90	0.08	0.67	0.08	0.73	353.0
1982-1991	0.07	0.75	0.10	0.63	0.15	0.35	529.8	0.05	0.85	0.13	0.71	0.08	1.09	298.2
1992-2001	0.07	1.11	0.13	0.61	0.15	0.41	599.2	0.04	1.73	0.25	0.75	0.08	1.71	316.0
2002-2011	0.05	1.00	0.14	0.63	0.15	0.53	537.4	0.02	1.66	0.27	0.70	0.05	2.23	216.9

C. $\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + \varepsilon_{it}$

	High tangible capital ratio firms							Low tangible capital ratio firms						
Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
1972-1981	0.017	5.64	0.360	14.06			0.15	0.004	3.14	0.177	9.92			0.10
1982-1991	0.022	8.75	0.211	13.54			0.14	0.010	5.34	0.078	8.04			0.09
1992-2001	0.016	8.42	0.131	10.14			0.14	0.005	7.65	0.031	7.28			0.07
2002-2011	0.010	7.62	0.092	10.84			0.13	0.003	4.97	0.014	3.84			0.04
1972-1981	0.018	5.84	0.147	3.22	0.494	4.98	0.16	0.004	3.22	0.143	4.11	0.179	1.00	0.10
1982-1991	0.023	9.12	0.043	1.32	0.401	5.34	0.15	0.010	5.96	0.039	1.74	0.217	1.54	0.09
1992-2001	0.017	9.33	-0.021	-0.82	0.375	6.21	0.16	0.005	7.95	0.013	2.02	0.130	3.16	0.07
2002-2011	0.011	8.22	0.012	0.69	0.209	4.34	0.14	0.003	5.01	0.007	1.17	0.076	1.25	0.05

Table 4
Investment-cash flow sensitivity: alternative explanatory variables

This table presents the five-year panel regressions of investment on the market-to-book ratio (MB), cash flow (CF), and the product term of CF with tangible capital (TC), WW index (WW), leverage (LR), cash holding (CH), working capital (WC), firm size (SZ) and cash flow volatility (CV). Panels A and B report the results without and with the term $\text{CF}_{it}\text{TC}_{i,t-1}$, respectively. The regression is estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level. NF is the average number of firms. R^2 is the adjusted R^2 for serially demeaned panel data.

$$\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{it} + a_3\text{TC}_{i,t-1}\text{CF}_{it} + a_4\text{WW}_{i,t-1}\text{CF}_{it} + a_5\text{LR}_{i,t-1}\text{CF}_{it} + a_6\text{CH}_{i,t-1}\text{CF}_{it} + a_7\text{WC}_{i,t-1}\text{CF}_{it} + a_8\text{SZ}_{i,t-1}\text{CF}_{it} + a_9\text{CV}_{i,t-1}\text{CF}_{it} + \varepsilon_{it}$$

A. Without $\text{TC}_{i,t-1}\text{CF}_{it}$

Period	MB	t-stat	CF	t-stat	TC*CF	t-stat	WW*CF	t-stat	LR*CF	t-stat
1972-1981	0.008	7.23	0.484	11.18			-0.260	-2.16	-0.272	-5.74
1982-1991	0.011	8.79	0.285	9.01			-0.187	-0.93	-0.107	-3.33
1992-2001	0.007	11.82	0.102	5.46			-0.058	-2.70	-0.082	-5.68
2002-2011	0.005	9.68	0.091	5.92			-0.164	-2.48	0.006	0.63
	CH*CF	t-stat	WC*CF	t-stat	SZ*CF	t-stat	CV*CF	t-stat	NF	R^2
	-0.283	-3.78	-0.135	-2.49	-0.021	-2.52	-0.809	-5.34	1553.3	0.14
	-0.188	-4.51	-0.107	-2.83	-0.015	-1.35	-0.266	-2.57	1466.7	0.11
	-0.119	-5.53	0.001	0.04	0.005	1.68	-0.062	-3.88	1575.4	0.11
	-0.056	-3.99	0.080	4.22	-0.015	-3.48	-0.012	-1.28	1322.9	0.09

B. With $\text{TC}_{i,t-1}\text{CF}_{it}$

Period	MB	t-stat	CF	t-stat	TC*CF	t-stat	WW*CF	t-stat	LR*CF	t-stat
1972-1981	0.008	7.51	0.091	1.62	0.657	9.50	-0.178	-1.54	-0.272	-5.85
1982-1991	0.012	9.36	0.004	0.10	0.545	10.78	-0.147	-0.85	-0.103	-3.29
1992-2001	0.007	11.66	-0.066	-3.42	0.388	11.15	-0.065	-4.22	-0.073	-4.77
2002-2011	0.005	10.22	-0.035	-2.20	0.309	10.57	-0.112	-2.42	0.000	0.01
	CH*CF	t-stat	WC*CF	t-stat	SZ*CF	t-stat	CV*CF	t-stat	NF	R^2
	0.074	0.93	0.213	3.83	-0.011	-1.33	-0.603	-4.05	1553.3	0.15
	0.079	1.79	0.156	4.24	-0.013	-1.30	-0.188	-1.86	1466.7	0.13
	0.046	2.16	0.157	6.50	0.005	1.84	-0.039	-2.55	1575.4	0.13
	0.061	4.26	0.167	8.72	-0.009	-2.48	-0.013	-1.35	1322.9	0.12

Table 5
Unconstrained firms vs constrained firms

For unconstrained firms and constrained firms classified by the Whited-Wu index, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment, cash flow, and sales regressions, respectively. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	Unconstrained firms							Constrained firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.08	1.16	0.12	1.70	0.33	1.10	1054.8	0.07	1.12	0.08	1.71	0.30	1.35	544.0
1982-1991	0.08	1.38	0.11	1.47	0.33	1.32	969.6	0.06	1.45	0.02	1.37	0.29	1.70	602.9
1992-2001	0.07	1.86	0.11	1.35	0.30	1.40	999.4	0.05	1.94	-0.04	1.23	0.24	2.06	753.5
2002-2011	0.04	1.85	0.09	1.13	0.24	1.46	842.1	0.03	2.00	-0.08	1.04	0.20	2.50	612.3

B. Standard deviation

	Unconstrained firms							Constrained firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.06	0.75	0.06	0.64	0.14	0.66	1054.8	0.07	0.69	0.09	0.74	0.13	0.75	544.0
1982-1991	0.06	0.71	0.08	0.60	0.15	0.80	969.6	0.07	0.95	0.14	0.72	0.15	1.07	602.9
1992-2001	0.05	1.33	0.10	0.60	0.16	0.97	999.4	0.06	1.61	0.24	0.70	0.16	1.47	753.5
2002-2011	0.04	1.13	0.11	0.58	0.15	0.97	842.1	0.04	1.53	0.25	0.68	0.16	1.87	612.3

C. $\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + \varepsilon_{it}$.

	Unconstrained firms							Constrained firms						
Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
1972-1981	0.006	4.97	0.351	19.92			0.16	0.011	6.08	0.187	13.50			0.10
1982-1991	0.009	6.80	0.222	20.40			0.14	0.015	7.82	0.106	12.44			0.09
1992-2001	0.007	9.08	0.142	15.69			0.15	0.008	11.08	0.037	8.39			0.06
2002-2011	0.005	7.07	0.086	14.54			0.11	0.006	9.84	0.025	6.59			0.06
1972-1981	0.007	5.79	0.139	5.51	0.643	8.28	0.18	0.012	6.42	0.116	4.12	0.240	2.48	0.10
1982-1991	0.011	8.46	0.025	1.42	0.631	10.45	0.17	0.015	8.04	0.032	2.14	0.268	4.68	0.10
1992-2001	0.008	10.03	-0.009	-0.71	0.570	12.25	0.19	0.008	11.21	0.009	1.29	0.122	3.77	0.07
2002-2011	0.006	8.81	-0.037	-4.11	0.508	11.59	0.18	0.006	9.83	0.013	2.77	0.057	2.29	0.06

Table 6
Cash flow, cash flow volatility, and tangible/intangible capital

This table presents the ten-year panel regressions of (A) cash flow on lagged cash flow, (B) cash flow on lagged cash flow and its cross-product term with tangible capital, and (C) the absolute value of the residual from (A) on tangible and intangible capital, scaled by total assets. CF, TC and IC are cash flow, tangible capital and intangible respectively, scaled by total assets. MB is the market-to-book ratio. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level. NF is the average number of firms. R^2 is the adjusted R^2 for serially demeaned panel data.

A. $\mathrm{CF}_{it} = b_0 + b_1\mathrm{CF}_{i,t-1} + \xi_{it},\ \ \sigma_\xi = \sqrt{Var(\xi_{it})}$							
Period	CF	t-stat			σ_ξ	NF	R^2
1972-1981	0.520	40.34			0.045	1599.6	0.29
1982-1991	0.395	25.20			0.077	1575.0	0.17
1992-2001	0.286	18.01			0.109	1755.7	0.12
2002-2011	0.320	22.73			0.110	1458.3	0.14
B. $\mathrm{CF}_{it} = b_0 + b_1\mathrm{CF}_{i,t-1} + b_2\mathrm{CF}_{i,t-1} * \mathrm{TC}_{i,t-1} + \tilde{\xi}_{it},\ \ \sigma_{\tilde{\xi}} = \sqrt{Var(\tilde{\xi}_{it})}$							
Period	CF	t-stat	CF*TC	t-stat	σ_ξ	NF	R^2
1972-1981	0.482	22.10	0.129	2.35	0.045	1599.6	0.29
1982-1991	0.359	13.51	0.127	1.75	0.077	1575.0	0.17
1992-2001	0.224	10.13	0.298	3.79	0.108	1755.7	0.13
2002-2011	0.276	13.54	0.229	2.90	0.110	1458.3	0.15
C. $\lvert\xi_{it}\rvert = e_0 + e_1\mathrm{TC}_{i,t-1} + e_2\mathrm{IC}_{i,t-1} + \xi^*_{it}$							
Period	TC	t-stat	IC	t-stat		NF	R^2
1972-1981	-0.004	-0.73	0.007	6.24		1599.6	0.0147
1982-1991	0.003	0.50	0.011	10.02		1575.0	0.0182
1992-2001	-0.004	-0.53	0.008	6.94		1755.7	0.0120
2002-2011	0.004	0.36	0.009	7.24		1458.3	0.0215

Table 7
More predictable cash flow vs less predictable cash flow

For firms with more versus less predictable cash flow, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment regression. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	Firms with more predictable cash flow							Firms with less predictable cash flow						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.07	1.20	0.11	1.60	0.30	1.30	181.8	0.07	1.08	0.08	1.82	0.29	1.34	127.0
1982-1991	0.07	1.44	0.12	1.52	0.32	1.53	151.8	0.07	1.59	0.00	1.29	0.29	1.69	120.0
1992-2001	0.06	1.68	0.10	1.31	0.32	1.35	171.7	0.06	2.24	-0.06	1.17	0.24	2.36	141.9
2002-2011	0.04	1.82	0.11	1.20	0.23	1.55	146.0	0.03	2.05	-0.08	0.97	0.20	2.53	119.9

B. Standard deviation

	Firms with more predictable cash flow							Firms with less predictable cash flow						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.05	0.72	0.05	0.59	0.13	0.66	181.8	0.07	0.56	0.10	0.85	0.14	0.84	127.0
1982-1991	0.05	0.68	0.06	0.62	0.15	0.89	151.8	0.07	1.02	0.16	0.72	0.15	1.05	120.0
1992-2001	0.05	0.93	0.09	0.54	0.17	0.88	171.7	0.06	1.83	0.26	0.65	0.16	1.77	141.9
2002-2011	0.03	1.03	0.08	0.50	0.14	0.88	146.0	0.04	1.52	0.26	0.66	0.16	1.99	119.9

C. $\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + \varepsilon_{it}$

	Firms with more predictable cash flow							Firms with less predictable cash flow						
Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
1972-1981	-0.001	-0.31	0.397	7.40			0.15	0.019	4.69	0.148	7.01			0.09
1982-1991	0.004	1.21	0.219	5.49			0.09	0.011	2.44	0.027	1.98			0.03
1992-2001	0.004	1.59	0.261	7.79			0.18	0.009	5.77	0.016	1.87			0.07
2002-2011	0.006	3.05	0.134	4.14			0.15	0.007	4.41	0.023	3.84			0.05
1972-1981	0.000	0.07	0.173	2.53	0.690	3.49	0.16	0.019	4.76	0.096	2.31	0.186	1.22	0.09
1982-1991	0.005	1.66	0.007	0.14	0.713	5.02	0.13	0.011	2.45	0.008	0.27	0.069	0.59	0.03
1992-2001	0.004	1.70	0.099	2.08	0.589	3.97	0.21	0.009	5.77	-0.002	-0.18	0.081	1.36	0.07
2002-2011	0.007	4.46	-0.104	-2.79	0.891	5.99	0.28	0.007	4.30	0.003	0.41	0.090	2.45	0.06

Table 8
Productivity of tangible and intangible capitals

Panels A and B of this table present the ten-year panel regressions of log sales on log tangible capital and log intangible capital, all unscaled, treating parameters as economy-wide ones and industry-wide ones respectively. Panel C reports the rank correlation of estimated slope coefficients across subperiods. *Sales, TC* and *IC* are total sales, tangible assets, and intangible assets respectively, unscaled by total assets. The regression is estimated recursively with weighted least square where the variance of the error term is assumed to be a linear function of the log total assets. The t-statistic to the right of an estimate is clustered at the firm-year level. NF ($\bar{\text{NF}}$) is the average number of firms. R^2 ($\bar{R}^2$) is the adjusted R^2 for serially demeaned panel data.

Sales regressions: $\ln Sales_{it} = c_0 + c_1 \ln TC_{i,t-1} + c_2 \ln IC_{i,t-1} + \eta_{it}, \quad \sigma_\eta = \sqrt{Var(\eta_{it})}$

A. Market-wide estimation

Period	ln TC	t-stat	ln IC	t-stat	σ_η	NF	R^2
1972-1981	0.478	26.38	0.358	19.98	0.25	1599.6	0.84
1982-1991	0.461	31.80	0.348	23.35	0.33	1575.0	0.69
1992-2001	0.461	34.10	0.349	24.77	0.37	1755.7	0.66
2002-2011	0.387	22.40	0.458	29.05	0.40	1458.3	0.67

B. Industry-wide estimation

Period	ln TC		ln IC		$\bar{\sigma}_\eta$	$\bar{\text{NF}}$	$\bar{R}^2$
	mean	std	mean	std			
1972-1981	0.422	0.211	0.379	0.519	0.22	128.0	0.78
1982-1991	0.422	0.293	0.350	0.375	0.26	125.0	0.66
1992-2001	0.445	0.231	0.311	0.328	0.26	140.5	0.70
2002-2011	0.402	0.402	0.452	0.313	0.26	119.4	0.70

Table 9
Tangible capital productivity vs intangible capital productivity

For firms with high TC productivity and low IC productivity and firms with low TC productivity and high IC productivity, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment regression, cash flow, and sales regressions, respectively. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	Firms with high TC and low IC productivity							Firms with low TC and high IC productivity						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.09	1.07	0.11	1.81	0.36	1.06	315.5	0.08	1.20	0.12	1.61	0.32	1.32	251.4
1982-1991	0.07	1.24	0.08	1.53	0.33	1.31	203.2	0.07	1.36	0.08	1.40	0.33	1.58	237.6
1992-2001	0.06	1.78	0.05	1.44	0.28	1.68	326.8	0.06	1.87	0.06	1.28	0.24	1.88	386.1
2002-2011	0.05	1.70	0.08	1.34	0.33	1.52	120.6	0.04	1.68	0.07	1.30	0.23	1.88	180.4

B. Standard deviation

	Firms with high TC and low IC productivity							Firms with low TC and high IC productivity						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.07	0.59	0.07	0.89	0.16	0.72	315.5	0.06	0.79	0.07	0.53	0.14	0.71	251.4
1982-1991	0.06	0.61	0.10	0.64	0.16	0.82	203.2	0.06	0.69	0.10	0.55	0.16	0.96	237.6
1992-2001	0.05	1.38	0.18	0.70	0.17	1.44	326.8	0.05	1.34	0.17	0.58	0.14	1.19	386.1
2002-2011	0.04	1.05	0.13	0.72	0.17	1.26	120.6	0.04	1.12	0.14	0.59	0.15	1.27	180.4

C. $\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + \varepsilon_{it}$

	Firms with high TC and low IC productivity							Firms with low TC and high IC productivity						
Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
1972-1981	0.007	1.79	0.339	11.34			0.14	0.008	3.29	0.273	8.64			0.10
1982-1991	0.004	1.49	0.210	8.97			0.13	0.017	3.45	0.124	6.77			0.08
1992-2001	0.009	7.56	0.077	9.59			0.10	0.012	9.16	0.043	4.27			0.10
2002-2011	0.006	2.61	0.084	5.17			0.10	0.006	3.29	0.045	4.42			0.07
1972-1981	0.008	2.28	0.077	1.64	0.714	5.42	0.16	0.008	3.48	0.139	2.74	0.431	2.95	0.11
1982-1991	0.007	2.39	0.054	1.33	0.493	3.80	0.14	0.017	3.51	0.032	1.02	0.304	2.66	0.08
1992-2001	0.009	7.72	0.017	1.37	0.287	3.81	0.12	0.012	9.29	0.000	-0.01	0.186	1.91	0.11
2002-2011	0.007	3.22	-0.037	-1.31	0.370	4.19	0.13	0.006	3.34	-0.015	-0.91	0.292	3.12	0.09

Table 10
Old-economy firms vs new-economy firms

For old-economy firms and new-economy firms, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment, cash flow, and sales regressions, respectively. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	Old-economy firms							New-economy firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.08	1.11	0.11	1.64	0.35	1.04	579.7	0.09	1.42	0.12	1.57	0.26	1.42	163.9
1982-1991	0.07	1.27	0.09	1.44	0.36	1.27	438.2	0.08	1.77	0.04	1.21	0.26	1.65	367.2
1992-2001	0.06	1.62	0.10	1.32	0.34	1.34	469.2	0.06	2.48	-0.02	1.09	0.21	2.00	551.6
2002-2011	0.04	1.61	0.09	1.21	0.28	1.39	384.5	0.03	2.33	-0.05	0.85	0.16	2.33	544.6

B. Standard deviation

	Old-economy firms							New-economy firms						
Period	INV	MB	CF	SA	TC	IC	NF	INV	MB	CF	SA	TC	IC	NF
1972-1981	0.05	0.67	0.06	0.61	0.15	0.66	579.7	0.08	0.89	0.09	0.51	0.11	0.61	163.9
1982-1991	0.05	0.54	0.08	0.59	0.16	0.83	438.2	0.07	1.09	0.15	0.55	0.13	1.00	367.2
1992-2001	0.04	0.88	0.09	0.57	0.17	1.00	469.2	0.06	1.94	0.25	0.65	0.14	1.40	551.6
2002-2011	0.03	0.84	0.09	0.55	0.15	0.99	384.5	0.04	1.59	0.25	0.59	0.13	1.76	544.6

C. $\text{INV}_{it} = a_0 + a_1 \text{MB}_{i,t-1} + a_2 \text{CF}_{i,t} + a_3 \text{CF}_{i,t} \text{TC}_{i,t-1} + \varepsilon_{it}$

	Old-economy firms							New-economy firms						
Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
1972-1981	0.010	4.83	0.314	13.92			0.17	0.008	3.69	0.197	8.61			0.14
1982-1991	0.006	2.29	0.192	11.76			0.12	0.015	8.09	0.110	9.63			0.12
1992-2001	0.009	4.62	0.147	10.53			0.16	0.008	11.29	0.033	6.37			0.07
2002-2011	0.005	3.87	0.093	9.33			0.11	0.006	10.82	0.025	6.20			0.07
1972-1981	0.011	5.21	0.059	1.76	0.744	6.89	0.19	0.009	3.90	0.119	2.90	0.305	1.99	0.14
1982-1991	0.007	2.95	-0.018	-0.63	0.617	6.37	0.15	0.015	8.66	0.003	0.18	0.419	5.37	0.13
1992-2001	0.009	4.80	-0.028	-1.58	0.549	7.79	0.20	0.008	11.39	0.007	0.88	0.124	2.80	0.08
2002-2011	0.007	4.82	-0.097	-5.99	0.640	10.43	0.21	0.006	10.95	0.005	1.04	0.112	3.37	0.08

D. $\text{CF}_{it} = b_0 + b_1 \text{CF}_{i,t-1} + \xi_{it}, \quad \sigma_\xi = \sqrt{Var(\xi_{it})}$

	Old-economy firms				New-economy firms			
Period	CF	t-stat	σ_ξ	R^2	CF	t-stat	σ_ξ	R^2
1972-1981	0.596	31.20	0.034	0.37	0.439	12.67	0.064	0.24
1982-1991	0.452	14.43	0.057	0.21	0.337	12.35	0.107	0.13
1992-2001	0.403	5.11	0.065	0.21	0.253	12.51	0.146	0.11
2002-2011	0.427	13.13	0.063	0.22	0.305	16.32	0.136	0.15

E. $\ln Sales_{it} = c_0 + c_1 \ln TC_{i,t-1} + c_2 \ln IC1_{i,t-1} + \eta_{it}, \quad \sigma_\eta = \sqrt{Var(\eta_{it})}$

	Old-economy firms						New-economy firms					
Period	ln TC	t-stat	ln IC	t-stat	σ_η	R^2	ln TC	t-stat	ln IC	t-stat	σ_η	R^2
1972-1981	0.538	18.30	0.307	10.07	0.213	0.86	0.425	9.34	0.386	8.40	0.290	0.87
1982-1991	0.515	20.97	0.274	11.47	0.282	0.67	0.410	14.08	0.396	13.09	0.387	0.68
1992-2001	0.528	23.39	0.283	12.74	0.292	0.75	0.427	17.21	0.393	16.61	0.455	0.54
2002-2011	0.530	16.42	0.360	12.83	0.293	0.83	0.366	12.64	0.473	15.95	0.483	0.51

Table 11
Balanced-panel firms

For two sets of balanced-panel firms, Panels A and B of this table present the ten-year-panel means and standard deviations, respectively, of physical investment (INV), cash flows (CF), sales (SA), tangible capital (TC), and intangible capital (IC), all scaled by total assets, and the market-to-book ratio (MB). MB, TC and IC are measured at the beginning of the year. NF is the average number of firms. Panels C, D and E present the results of the investment, cash flow, and sales regressions, respectively. The regressions are estimated with fixed firm effects. The t-statistic to the right of an estimate is clustered at the firm-year level.

A. Mean

	Period	INV	MB	CF	SA	TC	IC	NF
Panel 1	1972-1981	0.09	1.33	0.13	1.61	0.37	1.15	207
	1982-1991	0.08	1.35	0.11	1.42	0.38	1.41	207
Panel 2	1992-2001	0.06	1.74	0.12	1.38	0.31	1.58	262
	2002-2011	0.04	1.69	0.09	1.24	0.25	1.83	262

B. Standard deviation

	Period	INV	MB	CF	SA	TC	IC	NF
Panel 1	1972-1981	0.05	0.98	0.05	0.54	0.14	0.71	207
	1982-1991	0.04	0.60	0.07	0.52	0.16	0.87	207
Panel 2	1992-2001	0.05	1.08	0.08	0.59	0.15	1.08	262
	2002-2011	0.03	0.93	0.09	0.56	0.14	1.30	262

C. $\text{INV}_{it} = a_0 + a_1\text{MB}_{i,t-1} + a_2\text{CF}_{i,t} + a_3\text{CF}_{i,t}\text{TC}_{i,t-1} + \varepsilon_{it}$

	Period	MB	t-stat	CF	t-stat	CF*TC	t-stat	R^2
Panel 1	1972-1981	0.004	2.16	0.340	8.10			0.17
	1982-1991	0.007	2.45	0.171	6.84			0.11
	1972-1981	0.005	2.48	-0.003	-0.06	0.955	7.59	0.22
	1982-1991	0.008	3.22	-0.087	-2.38	0.749	6.15	0.16
Panel 2	1992-2001	0.005	2.83	0.150	8.31			0.13
	2002-2011	0.005	2.99	0.064	3.90			0.08
	1992-2001	0.006	3.12	0.039	1.30	0.366	4.17	0.15
	2002-2011	0.006	4.03	-0.064	-2.76	0.478	3.75	0.13

D. $\text{CF}_{it} = b_0 + b_1\text{CF}_{i,t-1} + \xi_{it}, \;\; \sigma_\xi = \sqrt{Var(\xi_{it})}$.

	Period	CF	t-stat	σ_ξ	R^2
Panel 1	1972-1981	0.670	23.80	0.46	0.029
	1982-1991	0.446	7.58	0.21	0.050
Panel 2	1992-2001	0.399	8.53	0.19	0.057
	2002-2011	0.409	8.11	0.20	0.073

E. $\ln Sales_{it} = c_0 + c_1 \ln TC_{i,t-1} + c_2 \ln IC_{i,t-1} + \eta_{it}, \;\; \sigma_\eta = \sqrt{Var(\eta_{it})}$

	Period	ln TC	t-stat	ln IC	t-stat	σ_η	R^2
Panel 1	1972-1981	0.487	12.66	0.403	7.96	0.189	0.88
	1982-1991	0.463	15.83	0.322	8.48	0.197	0.71
Panel 2	1992-2001	0.486	13.97	0.291	6.92	0.247	0.75
	2002-2011	0.442	12.37	0.438	9.18	0.303	0.77

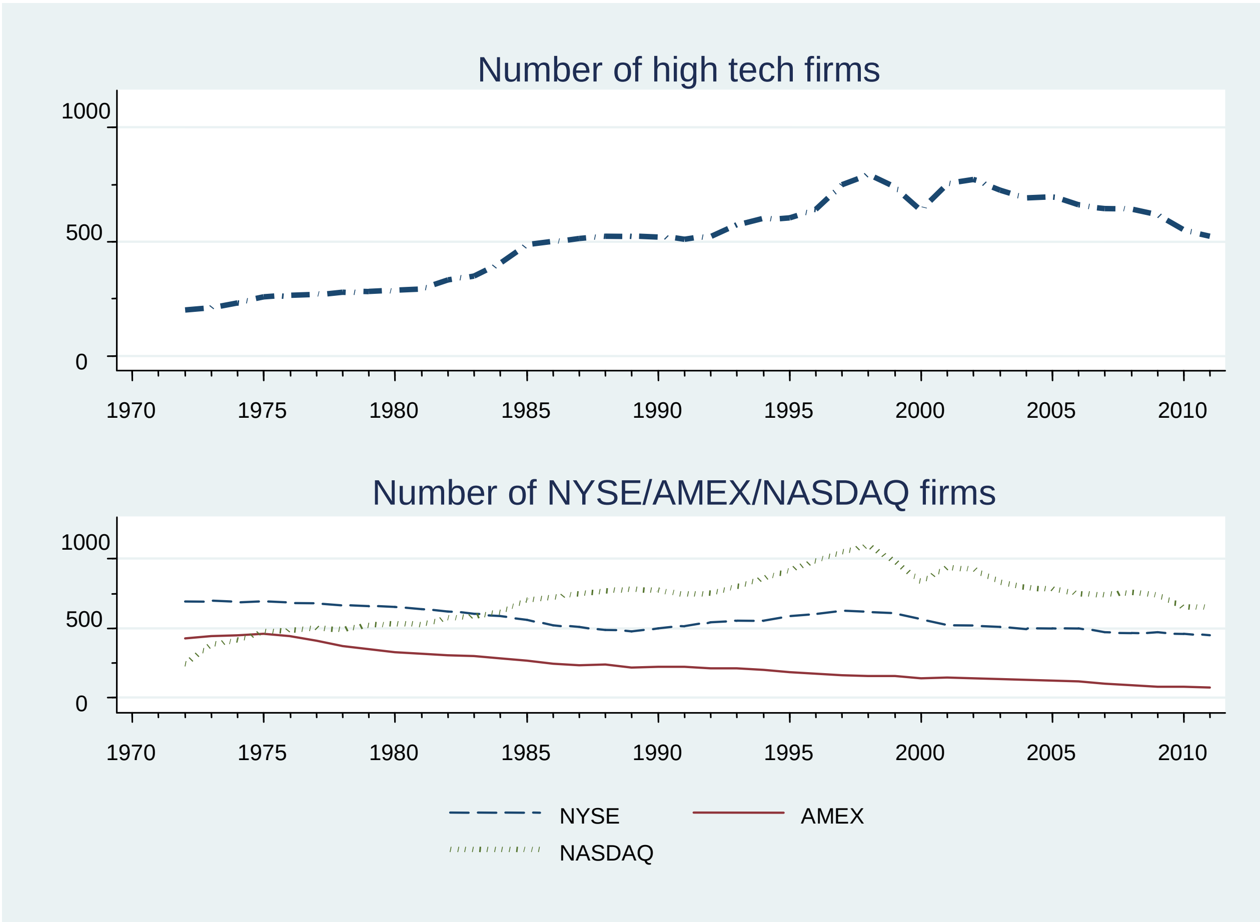

Figure 1. Number of high-tech firms and Firms listed on NYSE/AMEX/NASDAQ This figure shows the number of high-tech manufacturing firms (top panel) and that of manufacturing firms listed on NYSE, AMEX and NASDAQ (bottom panel).