Inventory Accumulation, Cash Flow, and Corporate Investment

by

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ABSTRACT

I show that firms' ability to adjust variable capital in response to productivity shocks has important implications for the interpretation of the widely documented investment-cash flow sensitivities. The variable capital adjustment is sufficient for firms to capture small variations in profitability, but when the revision in profitability is relatively large, limited substitutability between the factors of production may call for fixed capital investment. Hence, firms with lower substitutability are more likely to invest in both factors together and have larger sensitivities of fixed capital investment to cash flow. By building a frictionless capital markets model that allows firms to optimize over fixed capital and inventories as substitutable factors, I establish the significance of the substitutability channel in explaining cross-sectional differences in cash flow sensitivities. Moreover, incorporating variable capital into firms' investment decisions helps explain the sharp decrease in cash flow sensitivities over the past decades. Empirical evidence confirms the model's predictions.

DEDICATION

To Kyung, Jay, and Thea.

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Chapter 1: Introduction

A large body of corporate finance literature attempts to identify financing frictions and assess their effect on various corporate policies. However, judging whether a particular empirical relation is borne by capital market imperfections alone is difficult. For example, there is a nearly two decades-long debate in the literature on how to interpret the well-known empirical regularity in corporate investment: the adjustment of a firm's capital stock appears to respond strongly to the firm's cash flow even when one controls for Tobin's Q.[1] What seems missing in this debate, however, is a more careful examination of the firm's real-side decisions that may simply manifest themselves in the observed investment-cash flow sensitivities.[2]

In this paper, by exploiting the flexibility in the firms' investment decisions, I provide a novel perspective on the interpretation of investment-cash flow sensitivities. Using a parsimonious dynamic investment model that incorporates fixed and variable capital as substitutable production factors, I show that even in the absence of financing constraints, positive investment-cash flow sensitivities can be observed in empirical studies. More importantly, the model establishes that cross-sectional differences in the sensitivities are largely driven

[1] Starting with Fazzari, Hubbard, and Petersen (1988), empirical studies document positive significant coefficients on firm's cash flow in reduced-form investment regressions (see, e.g., Hubbard (1998) and Stein (2003) for literature surveys). However, the interpretation of positive investment-cash flow sensitivities as evidence of financing constraints has been challenged on several grounds, such as non-monotonicity results in empirical tests (e.g., Kaplan and Zingales (1997), Cleary (1999), and Hadlock and Pierce (2010)), measurement error in Q (Erickson and Whited (2000)), and investment-relevant information contained in cash flows (e.g., Poterba (1988), Gomes (2001), and Alti (2003)).

[2] Recent theoretical work shows the importance of recognizing real frictions, such as investment indivisibility, irreversibility, and time-to-build in capital investment, in explaining the cash flow sensitivities (see, e.g., Dasgupta and Sengupta (2007), Whited (2006), Whited (2009), and Tsoukalas (2011)).

by the heterogeneity in the extent to which firms substitute their variable capital for fixed capital investment. The empirical evidence lends strong support to the model's predictions.

The idea builds on the flexibility argument employed in the production-based asset pricing literature (e.g., Zhang (2005), Belo and Lin (2012), and Jones and Tuzel (2012)). Specifically, I consider value-maximizing firms that optimize their investment decisions over two factors of production. One of the factors is fixed capital, such as investment in machines, equipment, and plants, that is subject to relatively large convex adjustment costs and is partially irreversible. The other factor, variable capital, is less costly to adjust. Examples of variable capital include (but are not limited to) inventories, net working capital, and hiring of part-time labor. I assume that the firm's profit function exhibits decreasing return-to-scale in each factor of production and that substitutability between the two factors is limited.[3]

The key insight is as follows. The variable capital adjustment provides firms with the means of capturing, to some extent, their productivity shocks without having to invest in fixed capital. The firms' investments in their production factors respond optimally to variations in productivity, which evolves with random shocks but persists to some extent. The AR(1) process of firm productivity implies that the level of productivity each firm faces in one period forms the firm's expectation regarding the next-period productivity level. Thus a small, positive productivity shock observed today justifies a firm's investment

[3] The limited substitutability between variable and fixed capital can be viewed as a modeling choice, and can be replaced, with some caveats, by the modeling of excess capacity. The main intuition is that in response of positive productivity shocks, firms begin increasing variable capital first because it is subject to relatively low adjustment costs.

in its variable capital, such as inventories. In contrast, the small productivity change does not necessarily justify additional fixed capital investment, because such investment is more costly to adjust, and variable capital investment already partly substitutes for lack of fixed investment.[4] For example, one can imagine that as demand for a firm's products increases, the firm increases its input materials and hires more seasonal employees to improve the existing capacity's productivity. If there is a relatively large positive change in productivity or profitability, however, the marginal return to further increasing variable capital alone is limited, and the fixed capital investment is called for to capture such a large innovation. As a result, firms tend to skip investing in fixed capital in the periods of small productivity shocks but invest in fixed capital in response to a large innovation in their productivity and profits. In addition, while a firm invests in fixed capital, the previous variable capital investment, which tends to precede fixed capital investment, may further increase the firm's profits. Therefore, the firm's fixed capital investment is more likely to coincide with high cash flows.

More importantly, the model generates a cross-sectional prediction related to the degree of substitutability between the two factors of production. If, due to the nature of their technology, some firms more easily substitute variable capital for fixed capital, they are less likely to have high cash flows and fixed capital investment to coincide with each other. Therefore, the prediction is that a higher substitutability between variable and fixed investment implies a lower observed investment-cash flow sensitivity.

[4] The uncertainty in future productivity is important in the model. Unconstrained firms would immediately invest in fixed capital once they are sure that the average investment payoff exceeds the average cost. The fact that the productivity may drop in the next period makes such immediate investment suboptimal.

To explore this idea further, I analyze inventories as a form of variable capital.[5] I use both theoretical and empirical approaches to investigate whether the heterogeneity in the inventory-for-fixed capital substitution generates the cross-sectional differences in sensitivities of firm's fixed capital investment to their cash flows. I begin by building a neoclassical adjustment-cost model of investment that incorporates inventories and fixed capital as substitutable factors of production. The model allows me to study firms' investment policies in a frictionless world. I simulate a panel of firms and investigate the impact of the substitutability on investment-cash flow sensitivities. The model simulation results show that as the elasticity of substitution between two factors increases, firms' investment-cash flow sensitivities tend to decrease. Despite its parsimony, the model also matches well the key properties of real-side moments from the data, such as volatilities of inventory growth and fixed capital growth, volatility of inventory-to-capital ratio, and the correlation between inventory growth and fixed capital growth. These statistics are informative of the underlying economic mechanism that drives the cross-sectional differences in cash flow sensitivities and as such, provide a useful guide for constructing the empirical measure of inventory-capital substitution. I also find that recognizing inventories as a substitutable factor of production, when combined with the decrease over time in productivity persistence, helps explain the recent decline in the magnitude of cash flow sensitivities.

I then present empirical evidence that lends further support to the model's predictions. Guided by the model results, I construct measures of inventory-capital substitution based on

[5] In Appendix A, I discuss in detail the well-known empirical properties of inventory investment that support the view on inventories as a production factor.

the firm-level volatility of inventory-to-capital ratio and the firm-level correlation between inventory growth and fixed capital growth. In a series of tests, I find cash flow sensitivities decrease in the empirical measures of substitution. In all cases, the effect of financing constraints is controlled for via the two-way dependent sorting procedure, in which I use one of the *a priori* measures of financing constraints as the first sorting variable and the inventory-capital substitution measure as the second.[6] In addition, I examine how firm value changes in response to investments in inventories and fixed capital. The model suggests that firms with low substitutability between the two factors are more likely to benefit from simultaneous investment in inventories and fixed capital. Using the approach in Faulkender and Wang (2006), I regress firms' stock returns on the inventory and fixed capital investments and find that investing in both factors is greeted to a larger extent by the stock returns of low substitution firms.

To provide a more intuitive appeal, I perform an industry-level analysis by investigating the magnitude of cash flow sensitivity and selected variables across different manufacturing industries. I find that the distribution of industries in the substitutability measure is broadly consistent with the industry characteristics in terms of production technologies. I further examine the time trend in the cash flow sensitivities and find that despite the recent decline in the sensitivities, the effect of the inventory-capital substitution on investment-cash flow sensitivities holds over time.

My paper is related to two broad strands of existing literature. Modeling fixed cap-

[6] I use a firm age, size, Size-Age (SA) index, and the Kaplan-Zingales (KZ) index as proxies for financing constraints and report the results based on firm age and the KZ index in the empirical analysis section.

ital and variable capital as substitutable factors builds on the flexibility argument in the production-based asset pricing literature. For example, Belo and Lin (2012) and Jones and Tuzel (2012) incorporate inventories as a factor of production into firms' investment problems and show that the different abilities of firms to substitute inventory investment for fixed capital investment can generate the cross-sectional differences in risk and returns. In the model comparative statistics, the authors demonstrate that firms with low substitutability have relatively large amounts of fixed capital in a bad state of the economy. This strand of literature has also seen success in explaining other asset pricing puzzles, such as value premium (Zhang (2005)) and accrual anomaly (Wu, Zhang, and Zhang (2010)).[7] However, investment in variable capital, such as inventories, has been largely ignored in the corporate finance literature, which is surprising given the importance of such investment plays in firms' real decisions and the link to optimal capital investment dynamics.

A large body of literature constitutes the investment-cash flow sensitivity debate alone. For example, Kaplan and Zingales (1997) and Cleary (1999) provide evidence that investment-cash flow sensitivities are non-monotonic in the degree of financing constraints and can be higher for the firms that are least likely to be constrained according to their classification. Kaplan and Zingales (1997, 2000) set forth the research agenda to look for the correct economic meaning of the sensitivities.[8] Some papers employing a natural experiment approach

[7] Zhang (2005) argues that (partly) irreversible capital investment is riskier than growth options. The basis for this claim is, as he points out, the link between the risk and flexibility: "the risk of a firm is inversely related to its flexibility in utilizing its capital investment to mitigate the effects of exogenous shocks" (p. 86).

[8] Despite the ambiguous meaning, the investment-cash flow sensitivity became a popular metric in the literature that examines the impact of capital market imperfections on corporate investment (Stein (2003)). Numerous papers also use the sensitivities in drawing inference about the effect of other attributes, such as stock price (Baker, Stein and Wurgler (2003)), asset tangibility (Almeida and Campello (2007)), managerial

show that firms' investment is indeed sensitive to cash windfalls or shortfalls (e.g., Blanchard, Lopez-de-Silanes, and Shleifer (1994), Lamont (1997), and Rauh (2006)). However, although confirming the presence of frictions in an endogeneity-free setup, positive response of investment to windfalls does not explain precisely what mechanism drives the cross-sectional differences in cash flow sensitivities.[9]

Building on Poterba's (1988) comment on the measurement error in empirical Q, Erickson and Whited (2000), Gomes (2001), and Alti (2003) demonstrate the noisiness of empirical Q can result in a spurious effect of cash flows on investment decisions in the absence of financial frictions. The key idea is that the current productivity and firm's cash flows are informative about future growth opportunities.[10] While other studies show the measurement error problem alone does not explain away the cash flow sensitivities (e.g., Gilchrist and Himmelberg (1995), Agca and Mozumdar (2007, 2008), Almeida, Campello, and Galvao (2010), and Chen and Chen (2012)), none of these papers consider the primitive-level aspects of firms' real-side decisions as I do here.

A recent paper by Caggese (2007) is based on the insight that is related to mine. He derives from a structural model the relation between financing constraints and the pattern of the firms' investment in variable capital, and proposes the correlation between internal funds and variable-capital investment as a measure of financing constraint. The author,

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overconfidence (Malmendier and Tate (2005)), and investor protection (McLean, Zhang and Zhao (2011)), on investment policies.

[9] Another strand of literature focuses on the development of better measures of financing constraints (see, e.g., Kaplan and Zingales (1997), Lamont, Polk, and Saa-requejo (2001), Almeida, Campello, and Weisbach (2004), Whited and Wu (2009), Hadlock and Pierce (2010), and Ball, Hoberg, and Maksimovic (2012)).

[10] The persistence of productivity magnifies the role of cash flow in Q-theory investment models, because Q is akin to the expected marginal products of capital (Abel and Eberly (1994)).

however, does not consider the possibility that different firms may have different abilities to adjust variable capital. As my analysis suggests, the production-side optimization may have a strong impact on the variable capital adjustment and its correlation with internal funds.[11]

In sum, this paper contributes to two important sources of interest in the study of corporate finance. First, drawing a correct inference from the interaction between firms' investments and financing is a central issue for policy makers concerned with the impact of monetary policy transmission. Second, beyond its application in explaining the investment-cash flow sensitivities, the idea explored in this paper may have several implications for the dynamic behavior of various corporate policies. For example, by incorporating firms' motives for using variable capital, a real option model can provide a more precise prediction for the optimal time to invest in fixed capital, because the firms that are able to substitute variable for fixed capital can wait relatively longer before they increase the fixed capital. The use of variable capital may also affect the firms' debt maturity structure, because firms with more intensive use of variable capital are likely to prefer instruments with a shorter maturity.

The rest of the article proceeds as follows. The next chapter builds an investment model and reports the simulation results. Chapter 3 presents the empirical evidence, and Chapter 4 concludes.

[11] I note a possibility that a financially-constrained firm may *choose* to rely more on variable capital. In the long run, the firm may even push the production technology more suitable for substituting variable capital investment for fixed investments. Although not explored here, a model that accounts for the firms' endogenous choice of factor substitution may produce important implications about the corporations' financing and investment policies under frictions.

Chapter 2: The Model and Simulation

In this chapter, I build a dynamic investment model to investigate the effect of the substitutability of variable-for-fixed capital on the joint dynamics of firms' investments and cash flows. The model simulation results guide my empirical analysis that follows.

2.1 The Model Setup

As mentioned earlier, I define variable capital as a production factor input that is less costly to adjust than fixed capital. Throughout the paper, I analyze inventories as one form of variable capital. Building on the extant adjustment-cost models of investment, the model is parsimonious with an important distinction that it introduces the choice of variable capital by the firm. However, modeling variable capital such as inventories and labor is not entirely new in a broad set of economics literature (see, e.g., Kydland and Prescott (1982), Christiano (1988), Gomes, Kogan and Yogo (2009), Jones and Tuzel (2012), Belo and Lin (2012), and Bazdresch, Belo and Lin (2012)). Following these papers, I assume that the firm uses two factors of production, namely, fixed capital K and inventories N, to generate operating profits or cash flows CF according to the constant elasticity of substitution (CES) technology,

$$CF_t \equiv F(X_t, K_t, N_t) = e^{X_t}\left[s_k K_t^{-\gamma} + (1-s_k) N_t^{-\gamma}\right]^{\frac{-\alpha}{\gamma}} - f\ , \tag{1}$$

where X_t is the exogenous productivity state, $0 < \alpha < 1$ is the returns-to-scale parameter, f is fixed operating costs, $0 < s_k < 1$ is the relative weight on fixed capital, and γ is the parameter that determines the elasticity of substitution (ES $= 1/(\gamma + 1)$) between fixed capital and inventories.[12] The definition of the firm's operating profits reflects the assumption that the function $F(.)$ is a reduced form of the firm's profit-maximizing production function and does not include the investment and adjustment costs.

Productivity has a stationary and monotone Markov transition function $p_x\left(X_{t+1}|X_t\right)$ and follows the AR(1) process

$$X_{t+1} = \rho_x X_t + \sigma_x \epsilon_{t+1} \,, \tag{2}$$

where ρ_x is the persistence of productivity, σ_x is the conditional volatility, and ϵ_t is the random shock that is i.i.d. standard normal. The fixed capital and inventory stocks, respectively, evolve according to the accumulation rules,

$$K_{t+1} = \left(1-\delta_k\right) K_t + I_t^k \,, \tag{3}$$

$$N_{t+1} = \left(1-\delta_n\right) N_t + I_t^n \,, \tag{4}$$

where I_t^k and I_t^n, respectively, are the investments in fixed capital and inventories, and δ_k and δ_n, respectively, are the depreciation rates of the fixed capital and inventories.

The investments in fixed capital and inventories are subject to the adjustment costs,

$$GK\left(I_t^k, K_t\right) = \tfrac{c_k}{2}\left(\tfrac{I_t^k}{K_t}\right)^2 K_t \,, \tag{5}$$

$$GN\left(I_t^n, N_t\right) = \tfrac{c_n}{2}\left(\tfrac{I_t^n}{N_t}\right)^2 N_t \,, \tag{6}$$

where c_k and c_n, respectively, are the convex adjustment cost parameters for fixed capital and inventories. The specification of functional forms $GK\,(.)$ and $GN\,(.)$ above is standard

[12] As is well known, as $\gamma \to 0$ (ES $\to$ 1) in the limit, the bracket term in production function (1) simplifies to the Cobb-Douglas specification $\left[K^{s_k} N^{1-s_k}\right]^\alpha$; as $\gamma \to -1$ (ES $\to \infty$), it becomes a linear one $\left[s_k K + \left(1-s_k\right) N\right]^\alpha$; and as $\gamma \to \infty$ (ES $\to$ 0), it becomes a Leontief one $\left[\min\left\{K, N\right\}\right]^\alpha$.

in investment models.[13]

The firm's net payoff (or dividend) to its shareholders is given by

$$D_t \equiv F\left(X_t, K_t, N_t\right) - I_t^k - GK\left(I_t^k, K_t\right) - I_t^n - GN\left(I_t^n, N_t\right) \ .$$

Let V denote the cum-dividend firm value and $r_{t,t+\tau}$ the risk-adjusted discount rate between time t and $t+\tau$. At each period of time t, the firm chooses $\left\{I_t^k, I_t^n\right\}_{t=0}^{\infty}$ to maximize the present value of expected dividend stream

$$V\left(X_t, K_t, N_t\right) = \max_{\left\{I_t^k, I_t^n\right\}} \mathbb{E}_t\left[\sum_{\tau=0}^{\infty} \frac{D_{t+\tau}}{1+r_{t,t+\tau}}\right] , \tag{7}$$

subject to production function (1), the laws of motions (2)-(4), and the adjustment costs (5)-(6). The Bellman equation characterizing the firm value is

$$V_t = \max_{\left\{I_t^k, I_t^n\right\}} D_t + \mathbb{E}_t\left[\tfrac{1}{1+r} V_{t+1}\right] , \tag{8}$$

where V_t is the compact notation for the function $V\left(X_t, K_t, N_t\right)$. Then, taking the first-order conditions with respect to I_t^k and I_t^n, respectively, for the right-hand side of (8) yields the optimal investment rules,

$$1 + \tfrac{\partial GK_t}{\partial I_t^k} = \tfrac{1}{1+r} \int_X \left[\tfrac{\partial F_{t+1}}{\partial K_{t+1}} + (1-\delta_k)\left(1 + \tfrac{\partial GK_{t+1}}{\partial I_{t+1}^k}\right) + \tfrac{c_k}{2}\left(\tfrac{I_{t+1}^k}{K_{t+1}}\right)^2\right] p_x(X)\, dX \ , \tag{9}$$

$$1 + \tfrac{\partial GN_t}{\partial I_t^n} = \tfrac{1}{1+r} \int_X \left[\tfrac{\partial F_{t+1}}{\partial N_{t+1}} + (1-\delta_n)\left(1 + \tfrac{\partial GN_{t+1}}{\partial I_{t+1}^n}\right) + \tfrac{c_n}{2}\left(\tfrac{I_{t+1}^n}{N_{t+1}}\right)^2\right] p_x(X)\, dX \ , \tag{10}$$

where $\frac{\partial F_{t+1}}{\partial K_{t+1}}$ and $\frac{\partial F_{t+1}}{\partial N_{t+1}}$, respectively, are the marginal products of capital and inventories.

Conditions (9) and (10) establish, as in the standard Q-theory of investment, the link

[13] One could specify the cost function to reflect other frictions such as nonconvexity and (partial) irreversibility in capital adjustment. However, as I focus on the implications of introducing the variable capital for the firm's investment dynamics, I do not introduce other real-side frictions in my baseline setup.

between the marginal costs and benefits of investment. The left-hand-side terms, $1+GK_{I^k}$ and $1 + GN_{I^n}$, represent the marginal cost of investing in fixed capital and inventories, respectively, while the right-hand-side terms represent the discounted expected marginal benefits of doing so. The firm optimality implies that I^k and I^n are chosen to equate the marginal costs and benefits.[14]

Solving my model obtains the firm's investment decision as a function of the state variables, that is, productivity X_t, fixed capital K_t, and inventories N_t. Because the solutions to the firm's investment policies are not available in a closed form, I numerically solve the firm's dynamic optimization problem—technical details of the solution procedure are in Appendix B. Using the numerical solutions for the optimal investment policies and corresponding firm values, I simulate a panel of firms and study the model's implications. The model is solved and simulated at quarterly frequency, and then the quarterly quantities are aggregated to annual ones to be used as data for performing my tests.

2.2 Calibration

Table 1 summarizes the parameter values that I use to solve the model. Whenever possible, I choose the parameter values based on the values used in the previous studies. For the parameter values that are not readily available from the literature, I pick the one that best matches the empirical moments.

[14] The marginal products $\frac{\partial F_{t+1}}{\partial K_{t+1}}$ and $\frac{\partial F_{t+1}}{\partial N_{t+1}}$ in the conditions (9) and (10) take into account the parameter γ so that the ES does matter to the firm's optimal *mix* of investments in inventories and fixed capital.

Table 1: Model Parameter Values

This table presents the parameter values used to solve the investment model as described in the text.

Parameter	Notation	Value
Discount Rate	r	$0.05\frac{1}{4}$
Persistence of Productivity	ρ_x	$0.7^{1/4}$
Conditional Volatility of Productivity	σ_x	$0.29\frac{1}{\sqrt{4}}$
Depreciation Rate of Fixed Capital	δ_k	$0.12\frac{1}{4}$
Depreciation Rate of Inventories	δ_n	$0.24\frac{1}{4}$
Return-to-Scale	α	0.7
Fixed Operating Cost	f	$0.4\frac{1}{4}$
Adjustment-Cost Coeff for Fixed Capital	c_k	8
Adjustment-Cost Coeff for Inventories	c_n	2

First, the discount rate is set to $r = 0.05\frac{1}{4}$ to yield a discount factor of 0.99 quarterly, consistent with previous studies (see, e.g., Kydland and Prescott (1982), among others).

The next set of parameters is related to the firm's productivity process. I set the persistence of productivity to $\rho_x = 0.7^{1/4}$, which is taken from the estimation by Imrohoroglu and Tuzel (2011) and is also consistent with previous studies—for example, Zhang (2005) uses 0.97 ($= 0.7^{1/12}$) for the monthly frequency. Given the persistence and unconditional volatility (u_x), the conditional volatility of the auto-regressive process is calculated as $\sigma_x = u_x\sqrt{1-\rho_x^2}$. Imrohoroglu and Tuzel estimate the mean of cross-sectional standard deviations of the firms' productivities to be approximately 0.4, which yields $\sigma_x = 0.29\frac{1}{\sqrt{4}}$.

The third set of parameters describes the production technologies. Consistent with previous studies (see, e.g., Kydland and Prescott (1982), Alti (2003), and Zhang(2005), among others), the depreciation rate of fixed capital is set to $\delta_k = 0.12\frac{1}{4}$. The depreciation of inventories is often interpreted as the inventory-carrying costs, which practitioners estimate to be 19% to 43% annually (see Richardson (1995) and REM associates (2001)). Therefore, I set $\delta_n = 0.24\frac{1}{4}$, consistent with the values used by Gomes, Kogan, and Yogo (2009), Belo and Lin (2012), and Jones and Tuzel (2012).

Following Alti (2003), Cooper and Ejarque (2003), and Belo and Lin (2012), I set returns-to-scale to $\alpha = 0.7$. The fixed operating cost is set to $f = 0.4\frac{1}{4}$. As Zhang (2005) shows, the fixed operating cost lowers the model-generated Q (market-to-book ratio). It is worth noting that the models without systematic risk tend to overshoot market-to-book ratios unless the discount rate is unrealistically high—for example, Alti (2003) reports average Q of 2.5-5.8 from his model simulation results. Shutting down fixed operating cost does not affect any of my conclusions.[15]

Fixed-capital adjustment cost is set to $c_k = 8$ to generate the median volatility of fixed capital growth, SD[g^K], of approximately 0.08 and also to be roughly consistent with Zhang (2005). Inventory adjustment cost is set to $c_n = 2$ to generate the median volatility of inventory growth, SD[g^N], close to 0.15. It is worth noting that because there is only one type of uncertainty, namely, productivity shock, in the model economy, the overall volatilities of growth rates tend to be lower than the actual ones observed. I carry out extensive robustness checks with different values of c_k and c_n that generate reasonable volatilities of capital growth and inventory growth, as well as other moments, and find that these alternative parameter values have little impact on my main results.

Because I investigate the impact of the degrees of flexible substitution that are likely different across firms, I use a range of different values of γ. Previous studies provide little guidance on the elasticity of substitution between capital and inventories. For example, the value used for γ is 4 in Kydland and Prescott (1982) and 0.5 in Belo and Lin (2012), whereas unit elasticity (i.e., $\gamma \to 0$) is assumed in Gomes, Kogan and Yogo (2009). As Kydland and Prescott note, $\gamma < 0$ would make little sense. My basic strategy follows Jones and Tuzel (2012). Specifically, given each value of $0 < \gamma < 4$, I set the share of fixed capital s_k to generate the median inventory-to-capital N/K ratio of 0.8, which is close to the median N/K ratio of 0.85 in data (see Table 2).[16]

[15] Belo and Lin (2012) also note that setting $f = 0$ affects the market prices quite significantly but has little impact on the real-side quantities in their model.

[16] I intend the median of model-generated N/K ratios to be slightly lower than the empirical counterpart,

2.3 Model Implications

Using the panel of simulated firms from the model, I analyze whether the model can replicate empirical findings on investment-cash flow sensitivities among the U.S. manufacturing firms. The implementation of simulation and the description of the empirical sample and variables, respectively, are detailed in Appendices C and D.

because inventories observed in the data include the portion of finished goods that are left unsold.

Table 2: Effect of Substitutability on Cash Flow Sensitivities (Model Results)

This table reports the regression results and the medians of selected variables for the model-generated sample firms with different levels of substitutability. The regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, where a_i and a_t, respectively, are firm- and year- fixed effects, I^k is fixed capital investment divided by the beginning-of-period book assets, Q is Tobin's Q, and CF is cash flows divided by the beginning-of-period book assets. The first five columns display the results for the sample generated by the model simulation. The column headings show the different values of the substitutability (ES) used to solve the model. For the comparison purpose, the last column reports the estimates using the empirical sample of the Compustat U.S. manufacturing firms for the period of 1971-2009. The simulation procedure is described in Appendix C. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. SD[.] and CORR[.], respectively, denote the operators of standard deviation and correlation. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

	Model-Generated Sample					Empirical
	ES=0.25	ES=0.33	ES=0.50	ES=0.67	ES=0.91	Sample
	(γ =3)	(γ =2)	(γ =1)	(γ =0.5)	(γ =0.1)	
Regression Results:						
Q_{t-1}	0.044***	0.043***	0.043***	0.040***	0.041***	0.008***
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0005]
CF_t	0.184***	0.169***	0.147***	0.126***	0.091***	0.130***
	[0.0009]	[0.0009]	[0.0008]	[0.0008]	[0.0007]	[0.0044]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.604	0.589	0.568	0.542	0.529	0.347
Obs	400000	400000	400000	400000	400000	58789
Medians of Selected Variables:						
SD[N/K]	0.056	0.078	0.116	0.170	0.237	0.300
CORR[g^N, g^K]	0.862	0.830	0.780	0.743	0.693	0.436
SD[g^N]	0.116	0.129	0.143	0.156	0.178	0.217
SD[g^K]	0.085	0.086	0.083	0.081	0.077	0.171
N/K Ratio	0.784	0.788	0.795	0.813	0.882	0.853
Tobin's Q	2.341	2.307	2.275	2.287	2.307	1.164

2.3.1 Substitutability and Cash Flow Sensitivities

Panel A of Table 2 reports the estimation results for the conventional investment regression

$$I_{it}^{k} = b_1 Q_{it-1} + b_2 CF_{it} + a_i + a_t + \varepsilon_{it} \ , \tag{11}$$

where Q_{it} denotes Tobin's Q, which is the market value of firm V_{it} divided by the book value, $K_{it} + N_{it}$, and a_i and a_t are firm- and year- fixed effects, respectively. Variables I_{it}^{k} and CF_{it} are scaled by the beginning-of-period book value. For comparison purposes, the last column of Table 2 displays the estimates using the empirical sample of the Compustat U.S. manufacturing firms for the period of 1971-2009.[17] The results show that the elasticity of substitution (ES) between inventories and fixed capital generates considerable cross-sectional variation in investment-cash flow sensitivities. For example, the cash flow coefficient drops from a point estimate of 0.18 to 0.09 as the ES increases from 0.25 to 0.91.

Panel B of Table 2 reports the model-generated moments and their empirical counterparts calculated from the Compustat sample. Despite its parsimony, the model does a good job replicating key properties of the real-side quantities. The simulated firms have the median N/K ratios of 0.78-0.88, close to the one observed in data. The median volatility of inventory growth (0.12-0.18) and volatility of fixed capital growth (0.07-0.09) are slightly lower than the actual ones from data. The magnitude of these shortfalls, however, seems to be explained by the fact that only a single type of shock is driving the firms' investment

[17] In regressions using the empirical sample, the book values are the firms' total assets—see Appendix D.

decisions in the model. As discussed earlier, the model-generated Q, with median values of 2.28-2.34, are somewhat larger than the one observed in data due to the absence of systematic risk in the model. Nonetheless, the median Q values are similar across simulated firms with different ES, implying that the firm valuation *per se* is not driving the cross-sectional differences in investment-cash flow sensitivities in the model.

As mentioned earlier, observing the positive investment-cash flow sensitivities in the model may not be surprising, because the productivity is persistent. Poterba's (1988) comment and Alti's (2003) model share a similar insight that firms invest in production factor(s) to capture the expected future variations in productivity. In addition to this insight, another effect exists in the current setup I consider: when a firm invests in fixed capital, the firm's cash flows may be further increased by the previous inventory investment. That is, as the firm's inventory investment tends to precede fixed capital investment, it potentially magnifies the correlation between fixed capital investment and cash flows.

The intuition for why different ES produce the cross-sectional differences in cash flow sensitivity is also straightforward. The high ES firm is more likely to prefer to let inventory adjustment alone absorb the innovations in productivity while skipping fixed capital adjustment. To wit, by investing only in inventories in response to a positive productivity shock, a firm faces the following tradeoff: the firm can save on relatively large adjustment costs associated with fixed capital investment, but foregoes some incremental operating profits from investing in both factors together. The first unit of inventory-for-capital substitution is likely to make the firm better off, because by investing only in inventories, the firm attains a payoff close to the one it attains by investing in both factors, and at the same time saves the large fixed-capital adjustment costs. However, the next dollar of substitution does not do the same and is less appealing. The firm's ability to substitute inventories for fixed capital is therefore limited. For small productivity shocks, firms with high ES as well as those with low ES may find investing in inventories alone is sufficient. For a relatively large revision in productivity, however, the low ES firm has little leeway for substituting inventories for fixed capital and is likely to invest in both factors together, whereas the high ES firm may be able to take advantage of the substitution. Therefore, the low ES firms in the model tend to have high investment-cash flow sensitivities.

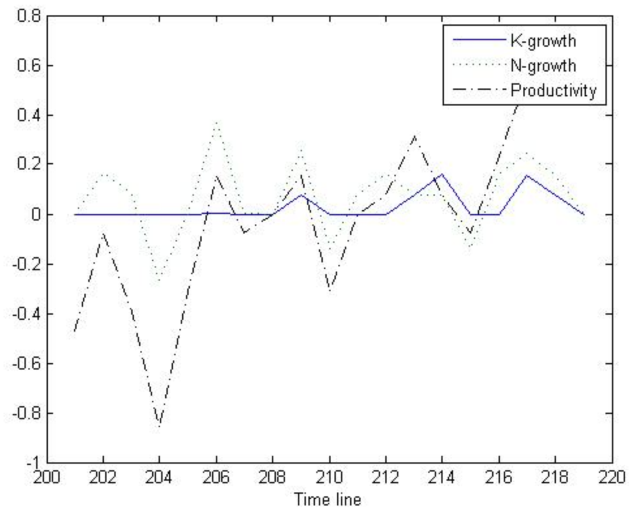
To illustrate this point, in Figure 1, I plot the sample paths of capital growth, inventory growth, and productivity innovations over time. In response to changes in productivity, the high ES firm (Panel A) tends to either skip its fixed capital investment altogether or make a relatively small fixed capital investment, whereas the low ES firm (Panel B) almost always adjusts both fixed capital and inventories together.

Figure 1: Simulated Sample Path of Fixed Capital Growth and Inventory Growth

This figure displays the sample paths of fixed capital (K) growth (solid line), inventory (N) growth (dotted line), and the productivity innovations (dashed dot line) over time for a simulated firm. The simulation procedure is described in Appendix C. Panel A and B, respectively, display the results for individual firms with different values for the ES parameter ρ_x. Each path is plotted for a sample period of 20 years.

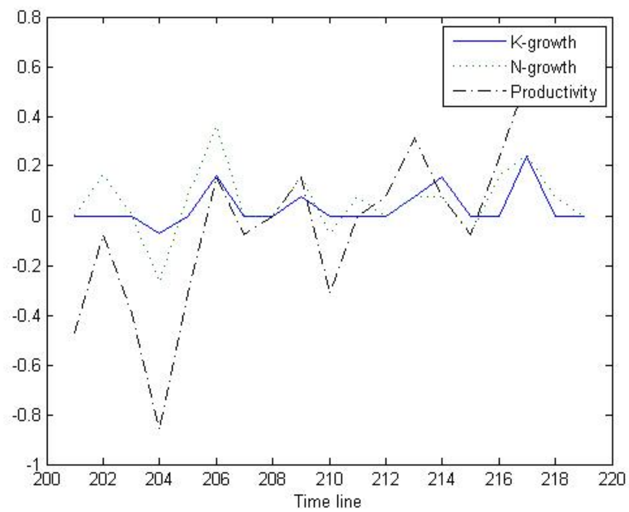
Panel A: High Substitutability

ES=0.67 (γ =0.5)



Panel B: Low Substitutability

ES=0.33 (γ =2)



Consistent with the explained mechanism, the average volatility of inventory-to-capital ratio, SD[N/K], is larger for the high ES firms, because these firms are less likely to adjust fixed capital at the time of inventory adjustment. For example, in Panel B of Table 2, volatility of the inventory-to-capital ratio is 0.24 for firms with ES = 0.91, whereas it is only 0.06 for firms with low ES (ES = 0.25). Similarly, the correlation between fixed capital growth and inventory growth, CORR[g^K, g^N], is relatively small for the high ES firms, implying that these firms require relatively less co-movement of two factors to achieve the optimal firm value.

To sum up, the model results suggest that the variable capital, such as inventories, and the firm's ability to substitute it for fixed capital investment, seem to play a crucial role in driving the cross-sectional differences in the cash flow sensitivities.

2.3.2 Productivity Persistence and Cash Flow Sensitivities

A number of recent papers document that the investment-cash flow sensitivities have substantially declined over past decades (see, e.g., Agca and Mozumdar (2008), and Chen and Chen (2012)). These empirical studies report the sensitivities of approximately 0.15-0.25 in the 1980s and 0.01-0.05 in the 2000s. The decrease in sensitivities may be interpreted as the improvement in U.S. firms' access to the capital markets, but it is so only if the cash flow sensitivities are indeed measuring firms' financing constraints. Chen and Chen challenge this interpretation on the grounds that the U.S. markets underwent a credit crunch between 2007 and 2009, for which they report cash flow sensitivities close to zero. The authors also examine a number of different possibilities (e.g., the role of cash reserves, R&D investment, corporate governance, and persistence in cash flows) but find that none of them are convincing explanations, thereby concluding the declining pattern is puzzling.

Chen and Chen, however, leave open the possibility of the effect of declining cash-flow persistence as a *partial* explanation for the decrease in sensitivities, and present evidence consistent with a decline in the persistence. If the productivity persistence becomes lower than before, a firm should rely less upon the current cash-flow state in making its investment decisions. Presumably, growing diversities in the consumers' tastes due to, for example, the introduction of new cultures, are likely to make overall demand more volatile or the life cycle of a particular product shorter, thereby making the individual firms' productivity less persistent. As Campbell, Lettau, Malkiel and Xu (2001) document, the idiosyncratic volatility of stock returns considerably increased between 1962 and 1997. The drop in the persistence of the firm's productivity is consistent with "an increase in the variance of cash-flow shocks" as suggested by Campbell, et al (p. 37).[18]

To explore the effect of the productivity persistence, I perform a series of tests with different values of persistence parameter ρ_x and report the results in Table 3. As ρ_x decreases, coefficients on cash flows drop considerably across firms with different ES (see first five columns). For example, when ρ_x changes from 0.7 to 0.6, the cash flow coefficient decreases by approximately 45%. These results are consistent with the discussed empirical findings—see also the empirical section of this paper for further discussion on this phenomenon. For comparison purposes, I carry out the same exercise using an alter-

[18] As one of the potential reasons for the increase in the variance of cash-flow shocks, the authors point out the tendency to break up the conglomerates and replace them with more specialized separate firms.

native model in which I shut down inventories N in the production function and allow the firm to optimize only over its investment in fixed capital. The results are displayed in the last column of Table 3. Notably, for the same decline in the persistence parameter, the sensitivities decrease only by 10%. The cash flow sensitivities, obtained from the alternative model, do not readily vanish unless the value of ρ_x is lowered to an extremely low level.[19]

These results suggest that taking into account the variable capital adjustment combined with the decrease in productivity persistence, yields a better explanation for the documented decline in empirical cash flow sensitivities.

Put together, the analysis here sheds light on the importance of variable capital adjustment in understanding the firms' dynamic investment decisions. The results suggest that recognizing the role of variable capital helps explain the empirical findings on investment-cash flow sensitivities in previous literature.

[19] In untabulated results, I find that for this alternative model, the cash flow coefficient drops to 0.04 when ρ_x is lowered to 0.2.

Table 3: Effect of Persistence on Cash Flow Sensitivities (Model Results)

This table reports the regression coefficients for the model-generated sample firms with different levels of substitutability. The regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, and the variable definition is the same as in Table 2. Panel A, B, and C, respectively, display the results when the productivity persistence ρ_x used in the model is set equal to $0.7^{1/4}$, $0.6^{1/4}$, and $0.55^{1/4}$. The estimates in Panel A, except for the last column, are the same as those in Table 2. In all cases, the first five columns display the results from the model simulation in which both inventory N and fixed capital K are used in the production function. The column headings show the different values for the substitutability (ES) used to solve the model. For the comparison purpose, the last column reports the results from the alternative model in which inventory N is shut down in the production function so that firms can optimize only over fixed capital K. The simulation procedure is described in Appendix C. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

	Model with Inventories (N) and Fixed Capital (K)					Model with
	ES=0.25	ES=0.33	ES=0.50	ES=0.67	ES=0.91	K only
	(γ =3)	(γ =2)	(γ =1)	(γ =0.5)	(γ =0.1)	
Regression Coefficients when ρ_x=$0.7^{1/4}$						
Q_{t-1}	0.044***	0.043***	0.043***	0.040***	0.041***	0.040***
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
CF_t	0.184***	0.169***	0.147***	0.126***	0.091***	0.297***
	[0.0009]	[0.0009]	[0.0008]	[0.0008]	[0.0007]	[0.0011]
Regression Coefficients when ρ_x=$0.6^{1/4}$						
Q_{t-1}	0.027***	0.027***	0.022***	0.024***	0.021***	0.022***
	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]	[0.0003]
CF_t	0.114***	0.107***	0.083***	0.072***	0.062***	0.267***
	[0.0007]	[0.0007]	[0.0007]	[0.0006]	[0.0006]	[0.0009]
Regression Coefficients when ρ_x=$0.55^{1/4}$						
Q_{t-1}	0.017***	0.016***	0.010***	0.013***	0.012***	0.012***
	[0.0003]	[0.0002]	[0.0002]	[0.0002]	[0.0002]	[0.0003]
CF_t	0.085***	0.076***	0.059***	0.044***	0.033***	0.248***
	[0.0006]	[0.0006]	[0.0006]	[0.0006]	[0.0005]	[0.0009]

Chapter 3: Empirical Analysis

In this section, I empirically examine whether the "inventory-capital substitution channel" has a differential effect on firms' investment-cash flow sensitivities. My analysis in the previous section suggests that to the extent that the firms are different in their optimal policy on adjusting inventories and fixed capital, investment-cash flow sensitivities should be larger for firms with relatively low substitution between the two factors. These low substitution firms are more likely to invest in fixed capital at the time of inventory investment. Similarly, if the low substitution firms are more likely to find it optimal to invest in inventories and capital together, the stock market valuation should reflect the intuition that adjusting both factors together is more valuable to these firms. Moreover, If the firms' substitutability affects fixed investment decisions and is an important determinant of the magnitude of cash flow sensitivity, the sensitivities across different industries should be broadly in line with the industry characteristics in terms of production technologies. Finally, the effect of inventory-capital substitution on cash flow sensitivities is likely to continue even if the declining productivity persistence has caused the empirical sensitivities to decrease over the past decades.

3.1 Design of Empirical Tests

To empirically test my hypotheses, I control for the extent to which firms are financially constrained, because the firms in the actual data, unlike the simulated counterparts in my model, are likely to face the real-world financing frictions. As numerous studies argue, financing-side concerns may (or should) produce relatively large cash flow sensitivities for financially constrained firms, an effect—if it exists—that I need to separate from that of inventory-capital substitution. Therefore, I split the sample firms into terciles on the basis of a measure of financing constraints and that of inventory-capital substitution (i.e., two-way dependent sorts). In sections that follow, I carry out a series of tests based on this sorting procedure. Empirical models used in each section are described therein. Below I elaborate on the proxies that I use for the firm stratification.

I follow the previous literature in using the firm age, firm size, Hadlock and Pierce (2010) Size-Age index (SA index), and Kaplan-Zingales index (KZ index, Lamont, Polk and Saa-requejo (2001)) as proxies for potential financing constraints. Hadlock and Pierce argue that the firm age and size are the most reliable (or the least ambiguous) a priori measures of financing constraints. The authors propose the SA index by estimating the ordered logit models, where they classify the degree of the firms' financing constraints on the basis of the qualitative analysis of the SEC filings of sample firms. The KZ index has also been extensively used as a measure of financing constraints (see, e.g., Baker, Stein and, Wurgler (2003), and Hennessy, Levy, and Whited (2007)). I find that using any of these proxies arrives at the same conclusion, and for brevity, report the results based on the firm age and KZ index.

To complete my firm classification scheme, I also need a measure of the firms' inventory-capital substitution. In developing measures for the extent to which the firms substitute inventories for fixed capital, I rely on two important statistics from the model simulation results, namely, the volatility of the inventory-to-capital ratio SD[N/K] and the correlation between inventory growth and fixed capital growth CORR[g^N, g^K] over time. As shown in the previous chapter, if the firm substitutes inventories for capital to capture productivity shocks, the correlation between inventory and fixed-capital growth rates becomes low, and the volatility of the inventory-to-capital ratio becomes high. In recent production-based asset pricing papers that model inventories and fixed capital as substitutable factors of production, Belo and Lin (2012) and Jones and Tuzel (2012) present similar results.[20]

In the actual data, however, the fluctuation in inventory stocks may be partly attributable to reasons other than the firms' investment policies in response to the productivity shocks. For example, a firm's forecasting errors regarding the production planning or product sales may give a rise to the volatility of the firm's inventories. This noise may be considerable for some firms, particularly those that are small and young. To address such a concern, in calculating the first measure, SD[N/K], I use the natural logarithm of the ratio of inventory to capital, that is, $\ln(N/K)$. Similarly for the second measure, CORR[g^N, g^K], I compute partial correlation, conditional on Q_{t-1}, between inventory growth and fixed capital growth, that is,

$$\mathrm{CORR}[g_t^N, g_t^K \mid Q_{t-1}] = \frac{\mathrm{CORR}[g_t^N, g_t^K] - \mathrm{CORR}[g_t^N, Q_{t-1}]\mathrm{CORR}[g_t^K, Q_{t-1}]}{\sqrt{1-\mathrm{CORR}^2[g_t^N, Q_{t-1}]}\sqrt{1-\mathrm{CORR}^2[g_t^K, Q_{t-1}]}},$$

to capture the co-movement of two investments controlling for investment opportunities. In

[20] Belo and Lin, in their Table 5, show that as ES increases, the correlation between inventory investment and capital investment drops. Jones and Tuzel note that "the greater substitutability allows firms to respond to shocks mostly by changing the more easily adjusted level of inventories, while [lower substitutability] causes them to change both types of capital more evenly." In their Table 12, the authors also show that as ES increases, the volatility of inventory growth becomes larger while that of capital investment remains about the same.

calculating these statistics, I require at least seven years of data for each firm to be included in the tests thereafter. I use all available observations of a firm over the entire period it appears, and report the test results based on such constructed measures. I note that a firm's substitution intensiveness may change over time, and therefore I perform the same tests using the measures constructed on the past 10-year statistics. In untabulated results where I employ the volatility of the plain N/K ratio or the usual correlation or where the measures on the basis of 10-year statistics are in place of the baseline measures, I find that the same conclusion is reached. Occasionally, these partitions of firms, classified according to the two-way sorts, are referred to as low, medium, and high substitution or SD (CORR) firms.

Table 4 displays the summary statistics of selected variables for the entire sample. The distribution of these variables among the whole sample aids my analysis as I later make a comparison on several firm characteristics between subsamples.

Table 4: Summary Statistics for Empirical Sample

This table reports the descriptive statistics of selected variables for the empirical sample. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. All variables are reported as a fraction of the beginning-of-period book assets unless defined otherwise, and are winsorized at 1% in both tails.

Variable	Mean	25th P	50th P	75th P	Obs
Inventories (N)	0.229	0.132	0.214	0.312	58798
Input Inventories	0.143	0.068	0.124	0.198	43540
Finished Good Inventories	0.094	0.035	0.074	0.129	47004
Fixed Capital (K)	0.281	0.162	0.258	0.375	58798
N/K Ratio	1.331	0.441	0.853	1.546	58798
Cash Flows (CF)	0.087	0.051	0.098	0.145	58798
Tobin's Q	1.490	0.908	1.176	1.687	58798
Total Assets (mil., $2008)	256.7	60.9	212.3	912.4	58798
SA Index	-3.400	-4.006	-3.387	-2.860	58798
KZ Index	0.314	-0.217	0.388	0.999	58798
Cash Holdings ($Cash$)	0.119	0.023	0.062	0.162	58798
Leverage (debt-to-asset)	0.216	0.079	0.206	0.321	58798
Debt Issue	0.067	0.000	0.005	0.071	58798
Equity Issue	0.020	0.000	0.002	0.009	58798
Altman's Z Score	4.42	2.57	3.54	5.04	58798

3.2 Does Inventory-Capital Substitution Effect Capture Differences in Empirical Cash Flow Sensitivities?

I begin my analysis by assessing whether the described inventory-capital substitution partitioning can capture the cross-sectional differences in cash flow sensitivities. Table 5 reports the estimation results for the investment regression equation (11), as well as descriptive statistics, for the two-way-sorted portfolios.[21] As displayed in Panel A, when the firms' age is controlled for as a financing-constraint proxy, the cash flow coefficient is 0.18 (0.16) for the low substitution group, whereas it is 0.097 (0.099) for the high substitution counterpart on the basis of SD sort (CORR sort). The coefficient difference test from the estimation of a seemingly-unrelated regression (SUR) system rejects the null that the coefficients are the same across groups—for age-SD sort (age-CORR sort), $\chi^2 = 118$ (63) and p-value < 0.001 (< 0.001). In addition, Figure 2 summarizes the cash flow coefficients for each intersection of the two-way sorts. The further investigation of each intersection confirms that the cash flow sensitivities decrease when moving from the low to the high substitution firms for all financing constraint sorts. The result is similar when the KZ index is used as the first sorting criterion, so I omit the analysis.

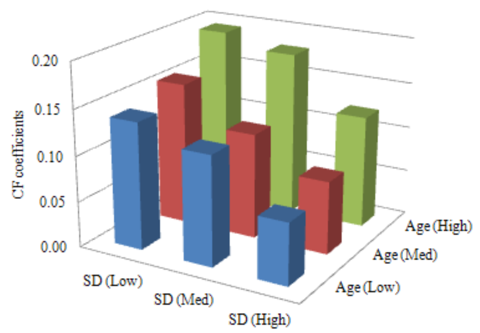
[21] In all cases, firm-fixed effects are included, and the standard errors are heteroskedasticity-consistent and clustered at the firm level.

Figure 2: Cash Flow Coefficients for the Intersections of Two-Way Sorted Empirical Subsamples

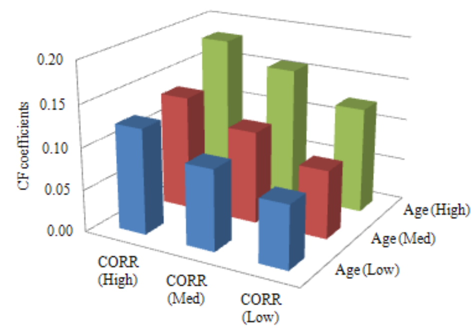
This figure reports the regression coefficients (bar graph) on cash flows for the empirical subsamples of firms with different levels of substitutability. The regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, where a_i and a_t, respectively, are firm- and year- fixed effects, I^k is fixed capital investment divided by the beginning-of-period book assets, Q is Tobin's Q, and CF is the sum of net income and depreciation divided by the beginning-of-period book assets. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substitutability measures, i.e., SD$[N/K]$ (columns 1-3) or CORR$[g^N, g^K]$ (columns 4-6). The regression is then run for each intersection of the two-way dependent sorted portfolios. On the front horizontal axis, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD$[N/K]$ (CORR$[g^N, g^K]$) measure.

Panel A: Financing Constraint Proxy: Firm Age

Two-way Dependent Sorts:
Age and SD$[N/K]$

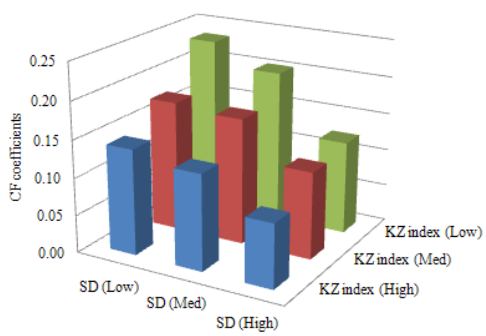


Two-way Dependent Sorts:
Age and CORR$[g^N, g^K]$

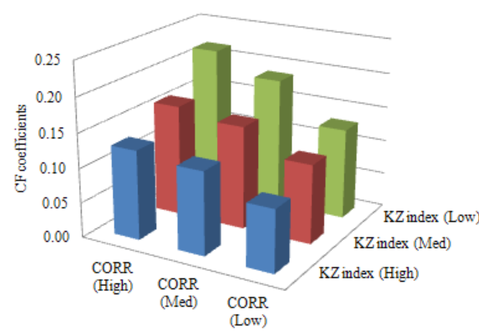


Panel B: Financing Constraint Proxy: KZ Index

Two-way Dependent Sorts:
KZ Index and SD$[N/K]$



Two-way Dependent Sorts:
KZ Index and CORR$[g^N, g^K]$



Turning to the real-side quantities, I first note that relatively low CORR[g^N, g^K] (high SD[N/K]) is observed for the high substitution firms when the partitioning is based on the SD (CORR) measure, which confirms that the classification scheme is consistent across the different combinations of the measures. Overall, the firm age, size, SA index, KZ index, and Tobin's Q are roughly similar across the different subsamples, implying that the potential financing constraints faced by these firms are likely similar.[22]

Kaplan and Zingales (1997) are the first to point out the "non-monotonicity" issue in investment-cash flow sensitivities, a commonly cited problem in interpreting a larger sensitivity as an indication of more severe financing constraints. Their critique is based on the fact that the sensitivities are not always increasing in the degree of financing constraints estimated from qualitative assessments of the firms' financial health (see also, e.g., Cleary (1999) and Hadlock and Pierce (2010) for similar findings).[23] The results presented in this section suggest that the non-monotonicity is partially attributable to the inventory-capital substitution effect because young and small firms tend to be more active in adjusting inventories (and perhaps other forms of variable capital).

[22] I note that the firm age and size (SA index and KZ index) tend to be smaller (greater) for the high substitution firms, but the difference is far from the inter-quartile ranges observed in the entire universe of the sample (see Table 4 for comparison).

[23] Moyen (2004) presents a potential explanation for why firms with low dividend ratios may exhibit high cash flow sensitivities even if they are unconstrained. In her model, the unconstrained firms can use more leverage. Therefore, these unconstrained firms pay a relatively small amount of dividends as a fraction of their assets, while investing in capital more actively when cash flows are high.

Table 5: Regression Results and Median Statistics for Empirical Subsamples

This table reports the investment regression results and the medians of selected variables for the subsamples of firms with different levels of substitutability. The regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, where a_i and a_t, respectively, are firm- and year- fixed effects, I^k is fixed investment divided by the beginning-of-period book assets, Q is Tobin's Q, and CF is the sum of net income and depreciation divided by the beginning-of-period book assets. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substituability measures, i.e., SD[N/K] (columns 1-3) or CORR[g^N, g^K] (columns 4-6). The regression is then run for each of three substituability groups. In the column headings, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD[N/K] (CORR[g^N, g^K]) measure. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

Table 5: (Continued)

Panel A: Financing Constraint Proxy: Firm Age						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	High	Med	Low
Regression Results:						
Q_{t-1}	0.008***	0.009***	0.008***	0.007***	0.009***	0.009***
	[0.0009]	[0.0009]	[0.0008]	[0.0009]	[0.0009]	[0.0009]
CF_t	0.179***	0.159***	0.097***	0.157***	0.142***	0.099***
	[0.0091]	[0.0087]	[0.0060]	[0.0084]	[0.0079]	[0.0069]
Constant	0.034***	0.033***	0.036***	0.035***	0.036***	0.035***
	[0.0015]	[0.0014]	[0.0014]	[0.0013]	[0.0015]	[0.0014]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.378	0.348	0.312	0.361	0.363	0.333
Obs	18958	19710	20121	19296	19679	19814
Medians of Selected Variables:						
Firm-level SD[N/K]	0.170	0.301	0.630	0.266	0.308	0.351
Firm-level CORR[g^N, g^K]	0.510	0.450	0.351	0.691	0.441	0.128
N/K Ratio	0.847	0.823	0.901	0.855	0.851	0.853
Cash Flows	0.105	0.101	0.091	0.099	0.102	0.095
Tobin's Q	1.121	1.163	1.217	1.177	1.173	1.144
Age	18.0	18.0	18.0	18.0	18.0	18.0
Total Assets (mil., $2008)	351.7	213.4	152.3	356.6	211.1	169.0
SA Index	-3.522	-3.399	-3.199	-3.511	-3.398	-3.255
KZ Index	0.329	0.392	0.445	0.443	0.384	0.332
Cash Holdings	0.048	0.060	0.090	0.054	0.062	0.074
Leverage (debt-to-asset)	0.225	0.207	0.179	0.234	0.202	0.176
Debt Issue	0.010	0.006	0.000	0.013	0.005	0.000
Equity Issue	0.001	0.001	0.002	0.002	0.002	0.001
Altman's Z Score	3.514	3.583	3.514	3.329	3.596	3.718

Table 5: (Continued)

Panel B: Financing Constraint Proxy: KZ Index						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	Low	Med	High
Regression Results:						
Q_{t-1}	0.008***	0.009***	0.008***	0.008***	0.009***	0.008***
	[0.0009]	[0.0010]	[0.0008]	[0.000]	[0.000]	[0.000]
CF_t	0.176***	0.161***	0.098***	0.157***	0.147***	0.100***
	[0.0093]	[0.0087]	[0.0059]	[0.0086]	[0.0081]	[0.0065]
Constant	0.033***	0.033***	0.036***	0.036***	0.036***	0.034***
	[0.0014]	[0.0016]	[0.0013]	[0.0013]	[0.0015]	[0.0014]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.381	0.353	0.317	0.365	0.362	0.325
Obs	18881	19818	20090	19407	19757	19625
Medians of Selected Variables:						
Firm-level SD[N/K]	0.170	0.299	0.651	0.262	0.310	0.358
Firm-level CORR[g^N, g^K]	0.512	0.447	0.347	0.691	0.439	0.127
N/K Ratio	0.847	0.809	0.916	0.842	0.848	0.874
Cash Flows	0.103	0.101	0.091	0.101	0.101	0.094
Tobin's Q	1.112	1.170	1.221	1.184	1.171	1.139
Age	17.0	19.0	17.0	19.0	19.0	16.0
Total Assets (mil., $2008)	352.1	231.6	142.0	378.0	215.2	159.0
SA Index	-3.482	-3.453	-3.186	-3.559	-3.446	-3.175
KZ Index	0.381	0.402	0.379	0.393	0.384	0.385
Cash Holdings	0.047	0.058	0.094	0.054	0.062	0.074
Leverage (debt-to-asset)	0.230	0.210	0.169	0.229	0.204	0.179
Debt Issue	0.011	0.006	0.000	0.012	0.005	0.000
Equity Issue	0.001	0.002	0.002	0.002	0.002	0.001
Altman's Z Score	3.48	3.56	3.61	3.37	3.58	3.69

Next, to investigate the possibility that the firms' previous cash reserves may have attenuated the role of cash flows, especially for the high substitution firms, I augment equation (11) with beginning-of-period cash holdings to estimate

$$I_{it}^{k} = b_1 Q_{it-1} + b_2 CF_{it} + b_3 Cash_{it-1} + a_i + a_t + \varepsilon_{it} \ . \tag{12}$$

Arguably, some firms may tend to rely more on their cash balances than cash flows to finance fixed capital investments. Had the substitution measures picked up such a tendency resulting in the low cash flow sensitivities for high substitution firms, then for these firms, a relatively large coefficient b_3 on cash holdings would be obtained. The result reported in Table 6, however, rejects this alternative explanation, showing that the cash holding coefficients are indistinguishable from zero for all groups. If the precautionary motive is, as Bates, Kahle and Stulz (2009) suggest, the primary reason for firms to hold cash, then the overall low response of the firms' fixed investment to their cash reserves is consistent with such an intuition.

Table 6: Cash-Augmented Regressions for Empirical Subsamples

This table reports the cash holdings-augmented regression results for the subsamples of firms with different levels of substitutability. The regression equation is $I_{i,t}^{k} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + b_3 Cash_{i,t-1} + a_i + a_t + \varepsilon_{i,t}$, where $Cash$ is cash holdings divided by the beginning-of-period book assets, and the variable definition for all other variables is the same as in Table 5. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substituability measures, i.e., SD[N/K] (columns 1-3) or CORR[g^N, g^K] (columns 4-6). The regression is then run for each of three substituability groups. In the column headings, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD[N/K] (CORR[g^N, g^K]) measure. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

Table 6: (Continued)

Panel A: Financing Constraint Proxy: Firm Age						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	High	Med	Low
Q_{t-1}	0.008***	0.009***	0.008***	0.007***	0.009***	0.009***
	[0.0009]	[0.0009]	[0.0008]	[0.0009]	[0.0009]	[0.0009]
CF_t	0.178***	0.158***	0.097***	0.157***	0.142***	0.100***
	[0.0091]	[0.0087]	[0.0060]	[0.0084]	[0.0079]	[0.0069]
$Cash_{t-1}$	-0.001	0.003	-0.005	0.006	0.002	-0.010*
	[0.0075]	[0.0062]	[0.0054]	[0.0068]	[0.0069]	[0.0056]
Constant	0.034***	0.033***	0.036***	0.034***	0.036***	0.035***
	[0.0016]	[0.0016]	[0.0015]	[0.0015]	[0.0016]	[0.0015]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.398	0.348	0.312	0.361	0.363	0.333
Panel B: Financing Constraint Proxy: KZ Index						
Q_{t-1}	0.008***	0.009***	0.008***	0.007***	0.008***	0.010***
	[0.0009]	[0.0010]	[0.0008]	[0.0009]	[0.0009]	[0.0009]
CF_t	0.176***	0.161***	0.098***	0.157***	0.147***	0.100***
	[0.0093]	[0.0086]	[0.0058]	[0.0085]	[0.0082]	[0.0068]
$Cash_{t-1}$	0.001	0.003	-0.005	0.007	-0.002	-0.006
	[0.0077]	[0.0063]	[0.0055]	[0.0069]	[0.0068]	[0.0056]
Constant	0.033***	0.033***	0.037***	0.035***	0.037***	0.035***
	[0.0014]	[0.0016]	[0.0015]	[0.0014]	[0.0016]	[0.0015]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.401	0.353	0.317	0.365	0.362	0.325

Finally, if inventory adjustment tends to precede the fixed capital investment and thus magnify the correlation between fixed capital investment and cash flows, one would expect that the inventory-investment variable loads significantly, even more so than cash flows, in the following regression

$$I_{it}^{k} = b_1 Q_{it-1} + b_2 CF_{it} + b_3 \Delta Inventories_{it} + a_i + a_t + \varepsilon_{it} \ . \qquad (13)$$

Table 7 reports the results. One can readily expect a relatively high coefficient b_3 on inventory investment for the low substitution firms, because CORR[g^N, g^K] tends to be high for these firms. In all cases, the coefficient b_3 is larger than the cash flow coefficient b_2. Moreover, introducing an inventory-investment variable pulls down the cash flow coefficients, especially for low substitution firms. For example, for low substitution firms, the coefficient drops from 0.18 (0.16) to 0.13 (0.12) when the firm stratification is based on age-SD (age-CORR) sort (see Panel A of Tables 5 and 7). The results suggest that a firm's inventory-investment decisions are based on the information set similar to the one contained in its cash flows. Therefore, including an inventory-adjustment variable in the regression makes cash flow variable less important.

Table 7: Inventory-Augmented Regressions for Empirical Subsamples

This table reports the inventory-augmented regression results for the subsamples of firms with different levels of substitutability. The regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + b_3 \Delta Inventories_{i,t} + a_i + a_t + \varepsilon_{i,t}$, where $\Delta Inventories$ is the change in inventories divided by the beginning-of-period book assets, and the variable definition for all other variables is the same as in Table 5. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substituability measures, i.e., SD[N/K] (columns 1-3) or CORR[g^N, g^K] (columns 4-6). The regression is then run for each of three substituability groups. In the column headings, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD[N/K] (CORR[g^N, g^K]) measure. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

Table 7: (Continued)

Panel A: Financing Constraint Proxy: Firm Age						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	High	Med	Low
Q_{t-1}	0.007***	0.008***	0.007***	0.006***	0.008***	0.009***
	[0.0009]	[0.0009]	[0.0007]	[0.0008]	[0.0008]	[0.0009]
CF_t	0.126***	0.119***	0.079***	0.115***	0.104***	0.092***
	[0.0086]	[0.0083]	[0.0056]	[0.0077]	[0.0075]	[0.0066]
$\Delta Inventories_t$	0.181***	0.157***	0.105***	0.216***	0.162***	0.046***
	[0.0073]	[0.0077]	[0.0065]	[0.0078]	[0.0069]	[0.0058]
Constant	0.037***	0.035***	0.037***	0.038***	0.038***	0.035***
	[0.0014]	[0.0014]	[0.0013]	[0.0012]	[0.0014]	[0.0014]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.416	0.375	0.326	0.407	0.392	0.336
Panel B: Financing Constraint Proxy: KZ Index						
Q_{t-1}	0.007***	0.008***	0.007***	0.006***	0.007***	0.009***
	[0.0008]	[0.0009]	[0.0007]	[0.0008]	[0.0009]	[0.0008]
CF_t	0.125***	0.122***	0.080***	0.111***	0.101***	0.092***
	[0.0085]	[0.0084]	[0.0057]	[0.0078]	[0.0077]	[0.0066]
$\Delta Inventories_t$	0.182***	0.155***	0.105***	0.215***	0.165***	0.051***
	[0.0073]	[0.0077]	[0.0066]	[0.0079]	[0.0071]	[0.0058]
Constant	0.036***	0.035***	0.037***	0.039***	0.038***	0.035***
	[0.0012]	[0.0015]	[0.0013]	[0.0012]	[0.0014]	[0.0014]
Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.420	0.379	0.331	0.411	0.391	0.328

To sum up, the results presented in current section support the main hypothesis that high substitution firms rely less on fixed capital investment and thus are less likely to encounter the concurrence of fixed capital investment and high cash flows. Although firms' cash flows are an important source of financing for their projects, firms' fixed-capital investment decisions may not necessarily be the function of this particular source of funds. Presumably, a firm's managers carefully plan out the fixed-capital investment projects and how to finance them. Conceivably, over the course of such a plan, firms increase inventories and other forms of variable capital to capture small variations in profitability.

3.3 Value of Investing in Both Factors Together

I now investigate the firm value implication of simultaneously investing in both inventories and fixed capital. The intuition is that if low substitution firms find it more optimal and therefore more valuable to invest in both factors together, the firm-value increase in response to an event of simultaneous investment should be larger for these firms. Because one cannot observe the exact "event date" of firms' investment decisions regarding inventories and fixed capital, the conventional stock-return event study is not feasible. Therefore, I follow the approach outlined in Faulkender and Wang (2006) and augment their excess-return regression model to include the variables of fixed capital investment and inventory investment. The resulting regression equation is

$$\begin{aligned} R_{it}^{ex} = {} & b_1 \Delta Cash_{it} + b_2 \Delta Earning_{it} + b_3 \Delta Div_{it} + b_4 \Delta Interest_{it} + b_5 \Delta R\&D_{it} \\ & + b_6 NetFin + b_7 MktLev_{it} + b_8 \Delta I_{it}^k + b_9 \Delta I_{it}^n + b_{10}(\Delta I_{it}^k \times \Delta I_{it}^n) + a_i + a_t + \varepsilon_{it} \ , \end{aligned} \tag{14}$$

where Δ is the compact notation for the first difference (one-year change) of a variable. All independent variables (defined below), except market leverage $MktLev_{it}$, are scaled by the lagged market value of equity (ME). As Faulkender and Wang explain, because the stock return is the growth of the market values of equities, i.e., $\frac{\mathrm{ME}_{it}-\mathrm{ME}_{it-1}}{\mathrm{ME}_{it-1}}$, the lagged ME normalization allows one to interpret the estimated coefficients as the dollar change in firm value for a one-dollar change in the corresponding independent variable. The coefficient b_{10} on the interaction term captures the marginal value of investing in inventories and fixed capital together.

Because some variables in equation (14) pertain to the current analysis only, I describe the definition of these variables—Compustat item names, if applicable, are in parentheses. $Earning_{it}$ is earning before interest expenses (IB+XINT+TXDI+ITCI), Div_{it} dividends (DVC), $Interest_{it}$ interest expenses (XINT), $R\&D_{it}$ research and development expenditures (XRD), $NetFin_{it}$ net issue of debt and equities (DLTIS+SSTK−DLTR−PRSTKC), $MktLev_{it}$ sum of short-term and long-term debt (DLC + DLTT) divided by sum of book assets (AT) and ME. For ΔI^n_{it}, I use both the first and second differences of inventories and report the results based on the first difference, because they yield the same conclusion. Finally, in calculating excess returns R^{ex}_{it}, benchmark returns are the annual returns on 25 Fama and French portfolios formed on ME and book-to-market equity ratio (BEME), where a portfolio return is a value-weighted return within each of the 25 portfolios. For each year, I group every firm into one of 25 ME and BEME portfolios based on the intersection between the ME and BEME independent sorts. Then, stock i's benchmark return at year t is the return of the portfolio to which stock i belongs at the beginning of fiscal year t.

Table 8 reports the results. Consistent with the hypothesis, the simultaneous investment tends to be more valuable to firms with low substitution. For example, the coefficient b_{10} on the interaction term is 0.93, 0.70, and 0.48 (0.9, 0.67, and 0.38) for the low, medium, and high substitution firms, respectively, when the firm classification is based on age-SD sort (age-CORR sort). It is worth noting that the analysis of the marginal value of investing in both factors relies mainly on the stock market's valuation. Therefore, the results here lend further support to the firm-level statistics SD[N/K] and CORR[g^N, g^K], serving as good measures of inventory-for-capital substitution.

Table 8: Stock-Return Regressions for Empirical Subsamples

This table reports the stock-return regression results for the subsamples of firms with different levels of substitutability. The regression equation is $R^{ex} = b_1 \Delta Cash_{i,t} + b_2 \Delta Earnings_{i,t} + b_3 \Delta Dividends_{i,t} + b_4 \Delta InterestExpenses_{i,t} + b_5 \Delta R\&D_{i,t} + b_6 NetFinancing_{i,t} + b_7 MktLeverage_{i,t} + b_8 \Delta I^k_{i,t} + b_9 \Delta I^n_{i,t} + b_{10}(\Delta I^k_{i,t} \times \Delta I^n_{i,t}) + \varepsilon_{i,t}$, where R^{ex} is the excess stock return over the return on one of Fama-French 25 ME-and-BEME benchmark portfolios, and ME and BEME, respectively, denote market capitalization and book-to-market ratio. All independent variables, except $MktLeverage$, are scaled by the beginning-of-period ME. The details of the sample construction appear in Appendix D. The variable definition for this regression analysis is found in Section 3. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substituability measures, i.e., SD[N/K] (columns 1-3) or CORR[g^N, g^K] (columns 4-6). The regression is then run for each of three substituability groups. In the column headings, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD[N/K] (CORR[g^N, g^K]) measure. The standard errors (in brackets) are robust to within-firm correlation and heteroskedasticity, and the statistical significance at the 10%, 5%, and 1% levels is denoted by *, **, and ***, respectively.

Table 8: (Continued)

Panel A: Financing Constraint Proxy: Firm Age						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	High	Med	Low
$\Delta Cash_t$	0.702***	0.712***	0.743***	0.715***	0.682***	0.672***
	[0.0594]	[0.0535]	[0.0549]	[0.0588]	[0.0585]	[0.0518]
$\Delta Earnings_t$	0.415***	0.462***	0.496***	0.431***	0.480***	0.465***
	[0.0322]	[0.0328]	[0.0329]	[0.0324]	[0.0336]	[0.0326]
$\Delta Dividends_t$	-0.213	0.221	1.245**	-0.283	-0.311	1.272**
	[0.766]	[0.779]	[0.535]	[0.891]	[0.778]	[0.468]
$\Delta InterestExpenses_t$	-2.041***	-2.945***	-2.304***	-2.215***	-2.714***	-2.180***
	[0.221]	[0.264]	[0.260]	[0.229]	[0.260]	[0.265]
$\Delta R\&D_t$	-0.263	-0.222	-1.667***	-0.554	-0.302	-1.948***
	[0.323]	[0.423]	[0.414]	[0.368]	[0.431]	[0.500]
$NetFinancing_t$	-0.103***	-0.044	-0.018	-0.091**	-0.004	-0.054
	[0.0385]	[0.0383]	[0.0389]	[0.0376]	[0.0372]	[0.0408]
$MktLeverage_t$	-1.061***	-1.016***	-0.967***	-1.034***	-1.070***	-0.986***
	[0.0438]	[0.0415]	[0.0398]	[0.0429]	[0.0406]	[0.0428]
ΔI_t^k	0.094*	0.128***	0.139**	0.143***	0.083*	0.154***
	[0.0498]	[0.0457]	[0.0559]	[0.0504]	[0.0480]	[0.0500]
ΔI_t^n	0.256***	0.216***	0.200***	0.255***	0.218***	0.185***
	[0.0393]	[0.0388]	[0.0413]	[0.0403]	[0.0457]	[0.0376]
$\Delta I_t^k \times \Delta I_t^n$	0.933***	0.704***	0.479**	0.904***	0.671***	0.385**
	[0.181]	[0.181]	[0.191]	[0.162]	[0.188]	[0.194]
Constant	0.194***	0.176***	0.148***	0.197***	0.177***	0.149***
	[0.0090]	[0.0081]	[0.0066]	[0.0088]	[0.0077]	[0.0076]
Adj. R^2	0.147	0.152	0.137	0.150	0.147	0.131
Obs	17855	18222	18576	17953	18297	18403

Table 8: (Continued)

Panel B: Financing Constraint Proxy: KZ Index						
	Subst. Measure: SD			Subst. Measure: CORR		
	Low	Med	High	High	Med	Low
$\Delta Cash_t$	0.689***	0.695***	0.738***	0.724***	0.667***	0.700***
	[0.0632]	[0.0523]	[0.0543]	[0.0595]	[0.0571]	[0.0532]
$\Delta Earnings_t$	0.421***	0.456***	0.496***	0.430***	0.463***	0.479***
	[0.0325]	[0.0325]	[0.0329]	[0.0327]	[0.0333]	[0.0324]
$\Delta Dividends_t$	-0.571	0.292	1.440***	-0.356	0.096	1.240**
	[0.806]	[0.808]	[0.519]	[0.894]	[0.710]	[0.490]
$\Delta InterestExpenses_t$	-2.051***	-2.828***	-2.407***	-2.246***	-2.554***	-2.349***
	[0.224]	[0.272]	[0.257]	[0.238]	[0.254]	[0.259]
$\Delta R\&D_t$	-0.248	-0.429	-1.565***	-0.587	-0.290	-1.885***
	[0.320]	[0.477]	[0.410]	[0.375]	[0.426]	[0.481]
$NetFinancing_t$	-0.098**	-0.051	-0.002	-0.095**	-0.040	-0.021
	[0.0390]	[0.0381]	[0.0391]	[0.0383]	[0.0366]	[0.0387]
$MktLeverage_t$	-1.115***	-1.042***	-0.954***	-1.011***	-1.046***	-1.005***
	[0.0455]	[0.0429]	[0.0402]	[0.0428]	[0.0408]	[0.0415]
ΔI_t^k	0.079	0.137***	0.135**	0.124**	0.103**	0.149***
	[0.0505]	[0.0453]	[0.0559]	[0.0517]	[0.0487]	[0.0486]
ΔI_t^n	0.271***	0.206***	0.202***	0.267***	0.247***	0.163***
	[0.0398]	[0.0390]	[0.0411]	[0.0402]	[0.0427]	[0.0397]
$\Delta I_t^k \times \Delta I_t^n$	0.939***	0.653***	0.527***	0.918***	0.688***	0.406*
	[0.183]	[0.173]	[0.195]	[0.168]	[0.174]	[0.211]
Constant	0.209***	0.183***	0.140***	0.190***	0.179***	0.149***
	[0.0095]	[0.0084]	[0.0066]	[0.0086]	[0.0076]	[0.0075]
Adj. R^2	0.150	0.155	0.138	0.148	0.145	0.137
Obs	17860	18270	18523	18030	18331	18292

3.4 Industry Analysis

I next investigate the patterns of cash flow sensitivity and substitutability across different manufacturing industries. The production-side substitutability is presumed to be largely determined by the characteristics of production technologies or product markets. One would expect, based on such characteristics, that some industries have a higher ability to substitute than others. For example, manufacturing computers or automobiles typically involves a fairly standardized process using flow or batch production. With standardized mass production technologies, the firms that operate in these industries are likely to be more active in adjusting input inventories in response to the expected profit opportunities. In contrast, firms that primarily engage in manufacturing stone or metal products are more likely to receive customized orders, with which they are less likely to benefit from inventory investment alone.

However, it would be extremely difficult, if not impossible, to construct a measure that determines the extent to which a firm or an industry uses a standardized manufacturing process that makes inventory adjustment valuable.[24] As developing such a measure is beyond the scope of the current paper, I instead aim to identify several representative industries in which either standardized production or customized production is prevalent. I note that the nature of analysis here is therefore largely qualitative and univariate.

Surveying the descriptive texts in the SIC Division Structure identifies the following

[24] In addition, the standardization of production alone may not be sufficient to justify the more active use of inventory adjustments. For example, although oil refining is presumed to be a highly standardized process, a refinery always runs at full capacity, and thus is unlikely to benefit much from adjusting input materials.

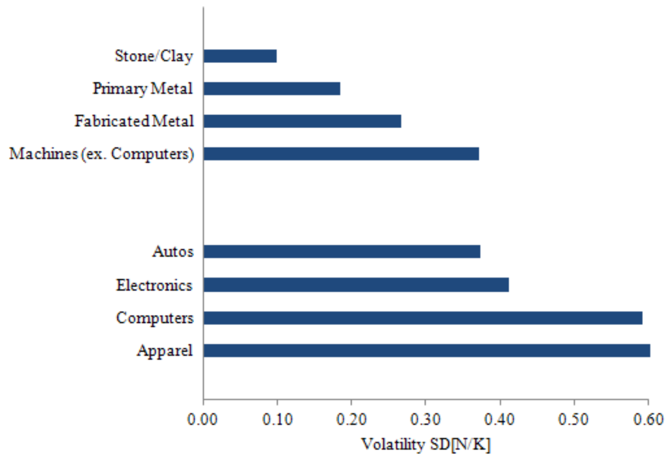
eight industries.[25] On one hand, it is reasonable to believe that the firms in such industries as Stone and Clay (SIC codes 3200-3299), Primary Metal (3300-3399), Fabricated Metal (3400-3499), or Industrial Machines excluding Computers (3500-3599, excluding 3570-3579) are more likely to involve a custom order-based production. On the other hand, a standardized mass-production seems quite common in Automobiles (3710-3719 and 3750-3759), Electronics (3600-3699), Computers (3570-3579), and Apparel (2300-2399) industries. Accordingly, these latter four industry groups are expected to have a relatively high ability to substitute inventory investment for fixed investment. If the substitutability affects firms' fixed investment decisions and thus is an important determinant of the magnitude of cash flow sensitivity, I expect that the sensitivities for the latter four industries are overall lower than the other four industries.

[25] The US Department of Labor SIC Division Structure describes the characteristics of products and the typical production process for each industry. The SIC manual is available from the Department of Labor website http://www.osha.gov/pls/imis/sic_manual.html.

Figure 3: Industry Distribution

This figure shows the industry distributions in volatility of N/K ratio (Panel A), cash flow coefficient (Panel B), and fixed investment rate (Panel C), respectively. Volatilities of N/K ratio and fixed investments divided by total assets are reported as industry-level medians. Cash flow coefficients are obtained by running the regression for each industry, where the regression equation is $I_{i,t}^{k} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, and the variable definition is the same as in Figure 2.

Panel A: Median Volatilities of N/K Ratio



Panel B: Cash Flow Coefficients

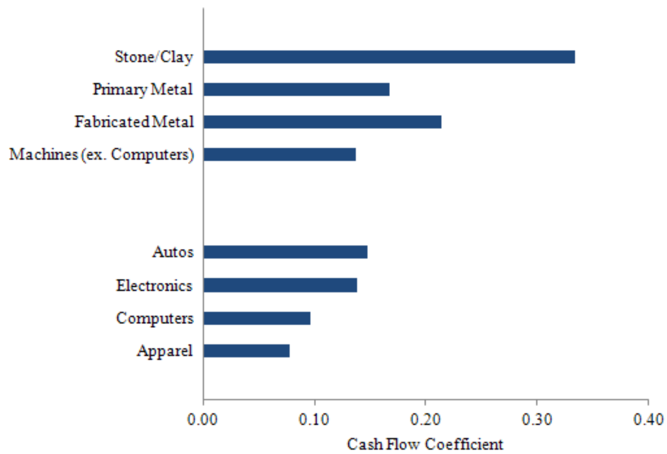


Figure 3: (Continued)

Panel C: Median Fixed Investment Rates

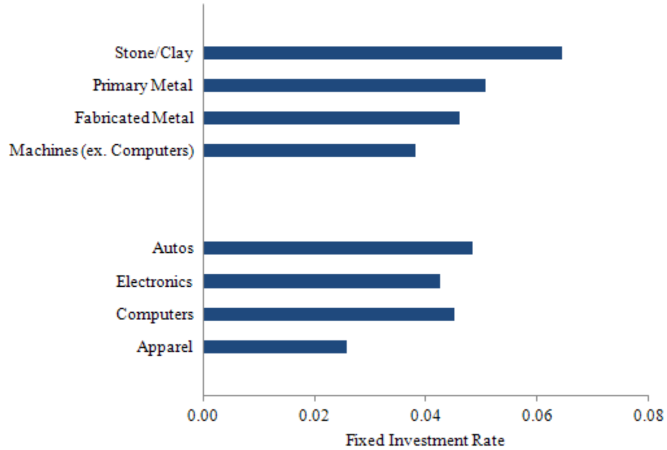


Figure 4: Industry Distribution in Substitutibility and Cash Flow Sensitivity

This figure plots the cash flow coefficient of each industry against its median volatility of N/K ratio. Volatilities of N/K ratio are reported as industry-level medians. Cash flow coefficients are obtained by running the regression for each industry, where the regression equation is $I^k_{i,t} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + a_i + a_t + \varepsilon_{i,t}$, and the variable definition is the same as in Figure 2.

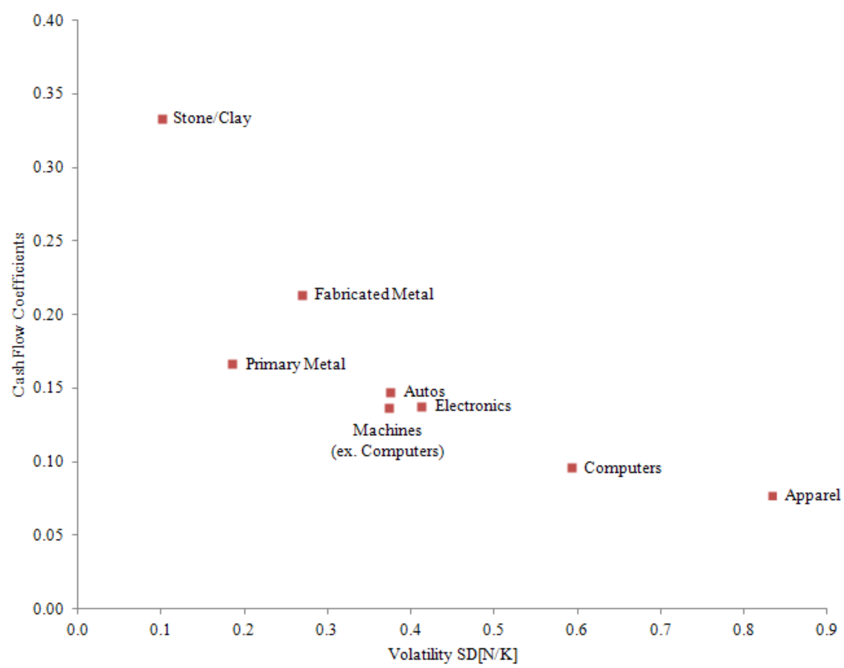


Figure 3 reports the volatility of N/K ratio SD$[N/K]$ (Panel A), the cash flow coefficients (Panel B), and fixed investments divided by total assets (Panel C) for each of eight industries. The volatilities and fixed investment rates are reported as industry-level medians, and the cash flow coefficients are obtained by running the regression equation (11) for each industry. Using industry means does not change my conclusion, and thus I omit reporting them. Inspecting the magnitude of reported statistics for each industry reveals that the industry distributions, respectively, in SD$[N/K]$, cash flow coefficient, and fixed investment rate are very consistent with what is expected from the industry characteristics in terms of product standardization and substitutability.

Stone and Clay, Primary Metal, Fabricated Metal, and Industrial Machinery industries all have lower SD$[N/K]$ and higher cash flow coefficients than Automobiles, Electronics, Computers, and Apparel industries. In addition, fixed investment rates are relatively low for the Automobiles, Electronics, Computers, and Apparel industries. Presumably, the products of these industries are subject to standardized mass production process using a batch or flow production, and therefore firms are more able to capture positive productivity shocks (or investment opportunities) by using inventory adjustments. In contrast, firms that operate in Stone and Clay, Primary Metal, Fabricated Metal, and Industrial Machinery industries are more likely to receive custom-tailored orders. Manufacturers of customized goods *ceteris paribus* would benefit less from inventory investments, and need to add physical capacities to exploit the expected positive moves in productivity or demand. As a result, these industries have low SD$[N/K]$ and high fixed investment rates.

Figure 4 plots the cash flow coefficient of each industry against its median SD[N/K]. The alignment of the industries in this two-dimensional space is stark, and strongly supports the claim that the cash flow sensitivity is overall lower for the industries with high substitutability. For the financing-constraint argument to make sense, one should be able to argue that, for example, a steel company is more financially constrained than a computer manufacturer or a clothing company. A more plausible explanation seems that the firms in a steel industry tend to rely more on fixed investments in plant equipment than those in a computer- or clothing- manufacturing industry.

3.5 Does Inventory-Capital Substitution Effect Hold over Time?

As discussed earlier, the empirical cash flow sensitivities have decreased over the past decades. If the inventory-capital substitution has a consistent effect on the cash flow sensitivities, the firm stratification based on the substitution measures, will capture the differences in the sensitivities over time. To check this hypothesis, using the regression equation (11), I run a Fama-MacBeth regression for 30 ten-year rolling windows starting with 1971-1980 and ending with 2000-2009. Each of the reported coefficients is the average computed from year-by-year regressions—i.e., ten regressions for each of 30 periods. Figure 3 summarizes the results.

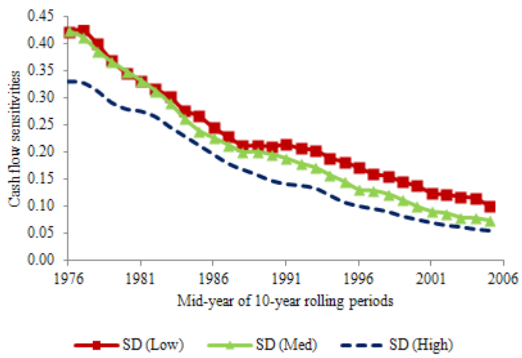
I first note that as documented in other studies, the cash flow sensitivities among all U.S. manufacturing firms have decreased from 0.39 in the 1970s to 0.21, 0.12, and 0.07 in the 1980s, the 1990s, and the 2000s, respectively (see Panel A of Figure 3). Despite such an overall decrease, however, the difference in the sensitivities between three groups consistently remains over time. In Panel B of Figure 3, when the firm classification is based on age-SD sort, the cash flow coefficients are 0.42, 0.24, 0.17, and 0.1 in 1970s, 1980s, 1990s, and 2000s, respectively, for low substitution firms, whereas they are 0.33, 0.19, 0.1, and 0.05, respectively, for high substitution firms. It is also noteworthy that the results are comparable to those from the model simulation (reported in Table 3). In sum, the inventory-for-capital substitution effect seems to drive consistently in different periods of time the cross-sectional differences in cash flow sensitivities.

Figure 5: Time Trend in Cash Flow Sensitivities

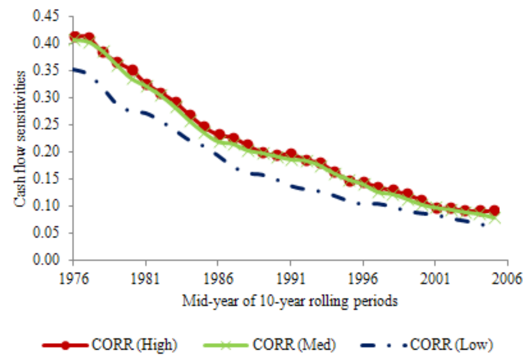
This figure reports the Fama-MacBeth regression coefficients on cash flows for the empirical subsamples of firms with different levels of substitutability. The regression equation is $I_{i,t}^{k} = b_1 Q_{i,t-1} + b_2 CF_{i,t} + \varepsilon_{i,t}$, and the variable definition, except for the fixed effects, is the same as in Figure 2. The regression is run year-by-year for each of 30 ten-year rolling windows, starting with 1971-1980 and ending with 2000-2009. Each of the 30 reported coefficients is the average computed from the ten year-by-year cross-sectional regressions. The sample consists of the Compustat U.S. manufacturing firms for the period of 1971-2009. The details of the sample construction and variable definition for the empirical analysis appear in Appendix D. The subsamples are formed via the following two-way dependent sorting procedure: the sample firms are first sorted on a financing constraint proxy, i.e., firm-age (Panel A) or KZ Index (Panel B), and then are re-sorted, within a given financing-constraint class, on one of the inventory-capital substituability measures, i.e., SD$[N/K]$ (columns 1-3) or CORR$[g^N, g^K]$ (columns 4-6). The Fama-MacBeth regression is then run for each of three substituability groups. In the plot legend, the labels "Low," "Med," and "High" ("High," "Med," and "Low") indicate, in that order, the low, medium, and high substitution groups, respectively, of firms sorted on the SD$[N/K]$ (CORR$[g^N, g^K]$) measure.

Panel A: Financing Constraint Proxy: Firm Age

Two-way Dependent Sorts:
Age and SD$[N/K]$

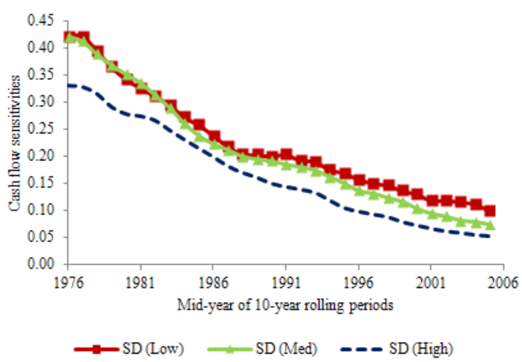


Two-way Dependent Sorts:
Age and CORR$[g^N, g^K]$

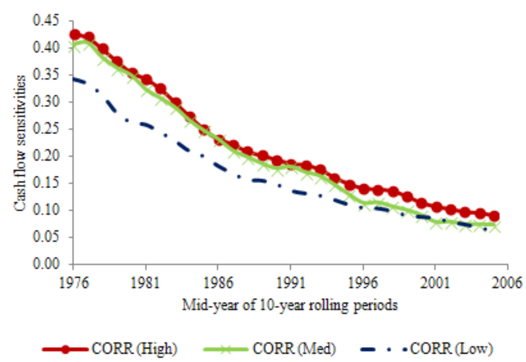


Panel B: Financing Constraint Proxy: KZ Index

Two-way Dependent Sorts:
KZ Index and SD$[N/K]$



Two-way Dependent Sorts:
KZ Index and CORR$[g^N, g^K]$



3.5.1 Reasons Why Substitutability of Inventories Might Have Increased

Because the focus of the current section is partly on the decrease over time in cash flow sensitivities, I briefly discuss potentially relevant aspects. In the model simulation, it is shown that if one takes into account the role of variable capital, a reasonable decrease in productivity persistence can explain the decline in cash flow sensitivities. Considering an increase in substitutability as another possible cause, combined with the story of productivity persistence, is therefore natural. Although it is difficult to formally assess whether the substitutability between the firms' fixed capital and inventories (or other forms of variable capital) has become higher over the past decades, I note several plausible reasons to believe it has. For example, the recent advances in logistics and management information systems, such as Enterprise Resource Planning or Just-in-Time practice, should allow firms to reduce their overall inventories and at the same time adjust them more flexibly. Seeing the improvement in resource management pulling down the level of inventory holdings is not counterintuitive, because firms have an incentive to keep inventory as low as possible insofar as their business is operational with the maintained level. With improved inventory management, firms are likely to more efficiently use the inventory adjustment to support their production and sales.

It is well known that the U.S. manufacturing firms have reduced their inventory levels over the past decades. For example, Chen, Frank, and Wu (2005) report median inventory-to-asset ratios of 26% in 1981 and 19% in 2000 and an average annual decrease of 2% over this period. The authors, more importantly, note that "the greatest reduction was found for work-in-process inventory" (p. 1015) whereas decrease in finished goods is relatively small. In their Table 1 (p. 1020), median ratios of raw materials, work-in-process, and finished goods to assets, are 9.2%, 5.4%, 7.9%, respectively, in 1981, whereas they are 4.5%, 1.3%, and 4.3%, respectively, in 2000. I verify that despite such a substantial decrease in inventory holdings, the mean (median) of SD[N/K] is 0.25 (0.21) in the 1970s and 0.33 (0.27) in the 2000s. Although the small number of time-series observations makes drawing a correct inference difficult, these statistics suggest that the firms may have gained more efficiency and flexibility in using different factors of production.

Chapter 4: Conclusion

Using the flexibility argument from the production-based asset pricing literature, I show that firms' ability to substitute variable for fixed capital has important implications for the corporate investment and cash flow dynamics. By modeling a firm that optimally invests in two factors of production in response to productivity innovations, I demonstrate that even in the absence of financing constraints, it is possible to observe positive investment-cash flow sensitivities. More importantly, firms with a higher substitutability between variable and fixed capital generally have lower cash flow sensitivities. This result is driven by the firms' tendencies to adjust variable capital in response to positive productivity shocks and to skip costly investment in fixed capital.

By analyzing inventories as a form of variable capital, I confirm in simulations of the model that the heterogeneity in elasticity of substitution between variable and fixed capital produces substantial cross-sectional variation in the estimated cash flow sensitivities. Specifically, if firms can substitute more easily between inventories and fixed capital, their cash flow sensitivities are lower in the model. I further confirm this intuition by conducting an empirical analysis of U.S. manufacturing firms over the period of 1971-2009. Using the volatility of inventory-to-capital ratios and the correlation between inventory and fixed capital growth rates as my proxies for inventory-for-capital substitution, I document that the investment-cash flow sensitivities are nearly twice as large for firms with low substitutability. Moreover, these differences remain significant even as I double-sort my sample on the measures of a priori financing constraints and inventory-capital substitution. The modeling of firms' optimal investment in inventories combined with the recent decline in productivity persistence, also allows me to explain why the investment-cash flow sensitivities have decreased so much over time (Chen and Chen (2012)).

Beyond its application to investment-cash flow sensitivities, the idea that firms can imperfectly substitute variable-for-fixed capital has several implications for the dynamic behavior of other corporate policies. For example, the model that allows for investment in variable capital can produce more precise predictions about the optimal time of real option exercises, choice of debt maturity structure, and capital structure rebalancing decisions. Therefore, I hope that this approach of modeling flexible factors of production will find its way into future corporate finance research.

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APPENDIX A

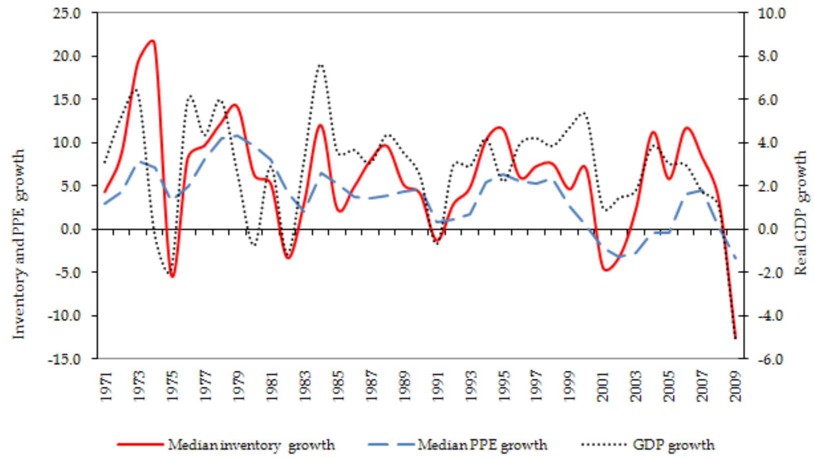
IMPORTANT PROPERTIES OF INVENTORY INVESTMENT

Brief discussion on the economic view on inventories is offered here. To explore my predictions, I analyze inventories as a form of variable capital. Therefore, I present some stylized facts about the inventory investment that help readers understand the view of inventories as a factor of production.

One of the most cited observations about inventories is the strong procyclicality of the aggregate inventory growth, which is well documented in macro economics literature—for example, Khan and Thomas (2007) report a correlation of 0.67 between aggregate inventory growth and real GDP growth. Figure A1 plots the time series of the medians of inventory growth and fixed capital growth along with real GDP growth. Similar to the documented pattern of aggregate inventory growth, the firm-level inventory accumulation is also highly correlated (correlation 0.61) with overall economies—more so than the fixed capital growth is (0.36). I find similar results for the mean and 25th and 75th percentiles. The procyclicality of inventory investment, as well as the considerable amount of inventory holding (23% of the manufacturing firms' assets on average), is difficult to explain if we ignore the productive role of inventories.

Figure 6: Inventory Growth, Fixed Capital Growth, and GDP Growth

This figure displays inventory growth (solid line), fixed capital (PPE) growth (dashed line), and real GDP growth (dotted line) for the period of 1971-2009. Inventory growth and fixed capital growth are the medians of the Compustat sample of U.S. manufacturing firms.



The view of inventories as a factor of production is further supported by the fact that manufacturers' input inventories (i.e., raw materials and work-in-process goods) not only account for a larger fraction of total inventories, but also exhibit a greater volatility, than finished goods (e.g., Blinder and Maccini (1991), Khan and Thomas (2007), Belo and Lin (2012), Jones and Tuzel (2012)).[26] The predominance of input inventories in the inventory composition implies that firms' inventory-holding motive is linked to their business prospects, rather than production-smoothing (Blinder and Maccini (1991)).

Another important fact is that firms' inventory adjustment tends to precede fixed capital adjustment. Figure A2 displays the analysis of cross-correlation between fixed capital growth and inventory growth. In each panel, the bar graph in the middle indicates the correlation in the concurrent period, say, $\mathrm{CORR}[g_t^K, g_t^N]$. The bars to the left of the middle display $\mathrm{CORR}[g_t^K, g_{t-1}^N]$, $\mathrm{CORR}[g_t^K, g_{t-2}^N]$, and so on, whereas those to the right display $\mathrm{CORR}[g_t^K, g_{t+1}^N]$, $\mathrm{CORR}[g_t^K, g_{t+2}^N]$, and so on. Panel A, for which medians of the Compustat sample are analyzed, shows that the one-year lead correlation $\mathrm{CORR}[g_t^K, g_{t-1}^N]$ is 0.37 and is statistically significant whereas the one-year lag correlation $\mathrm{CORR}[g_t^K, g_{t+1}^N]$, being 0.18, is smaller and statistically insignificant. Similarly, the analysis using the quarterly aggregate data also confirms that inventory growth leads fixed capital growth by about eight quarters whereas fixed capital growth's "lead" effect is relatively small (see Panel B).[27] The analysis using the median growth of the

[26] It is worth noting that even finished goods play productive roles such as display and demonstration of the products.

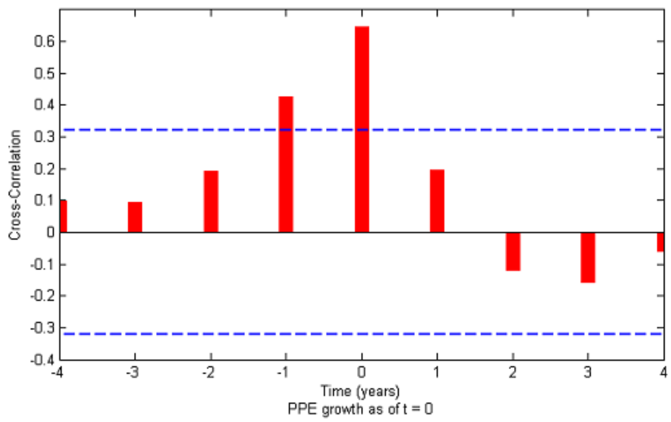
[27] The aggregate data items are obtained from the Federal Reserve Statistical Release Z.1 "Flow of Funds Accounts", Table B.102 "Balance Sheet of Nonfinancial Corporate Business." Inventories are "inventories," and fixed capital is the sum of "equipment" and "nonresidential structures," all of which are at their replacement

number of employees in place of inventory growth (Panel C) arrives at the same conclusion. Because fixed capital investment also calls for variable capital investment and vice versa, the fact that the two types of capital lead each other (i.e., positive correlation at both times $t-1$ and $t+1$) should not be surprising. What is intriguing in the cross-correlation analysis is that variable capital investment has a more pronounced lead effect than fixed investment. Therefore, the results suggest that in response to productivity shocks, the firms begin increasing their variable capital, such as inventories and labor, before investing in fixed capital.

costs as reported.

Figure 7: Cross-Correlation between Fixed Capital Growth and Variable Capital Growth
This figure reports the cross-correlation between fixed capital (PPE) growth and variable capital growth for the period of 1971-2009. Panel A displays the cross-correlogram for the annual medians of fixed capital growth and inventory growth of the Compustat sample of U.S. manufacturing firms. Panel B shows the one for the aggregated fixed capital and inventories of U.S. nonfarm- and nonfinancial- corporations, where Fixed capital is the sum of "Equipment" and "Nonresidential Structures" in Table B.102 of Federal Reserve Statistical Release Z.1, and inventories are "Inventories" in the same table. In Panel C, the median growth of the number of employees of the Compustat sample is in place of the median inventory growth. Each bar graph displays the cross-correlation calculated between fixed capital growth in current period, say t, and the lags and leads (three years for Panels A and C and twelve quarters for Panel B) of variable capital growth. For example, the bar shown on the time $t - -1$ is the correlation between fixed capital growth at t=0 and variable capital growth at $t - -1$, and the bar on the time $t+1$ is the one between fixed capital growth at t=0 and variable capital growth at $t+1$. The usual correlation is the bar displayed on time t=0. Dashed lines are the upper and lower confidence bounds, assuming that the two series are completely uncorrelated.

Panel A: Median Fixed Capital Growth (t=0) and Inventory Growth ($t-3$, ..., $t+3$)



Panel B: Aggregate Fixed Capital Growth (t=0) and Inventory Growth ($t-12$, ..., $t+12$)

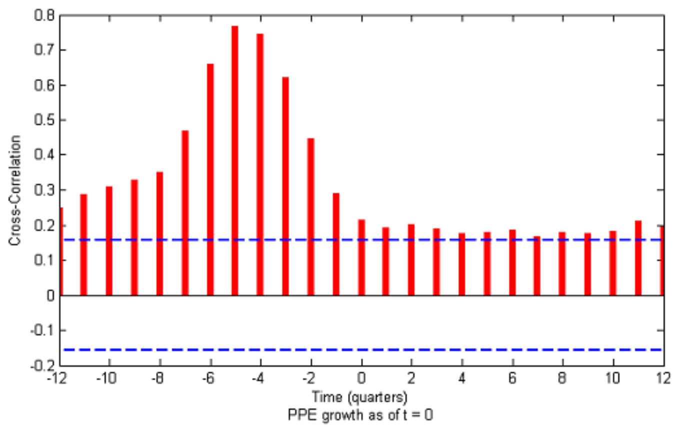
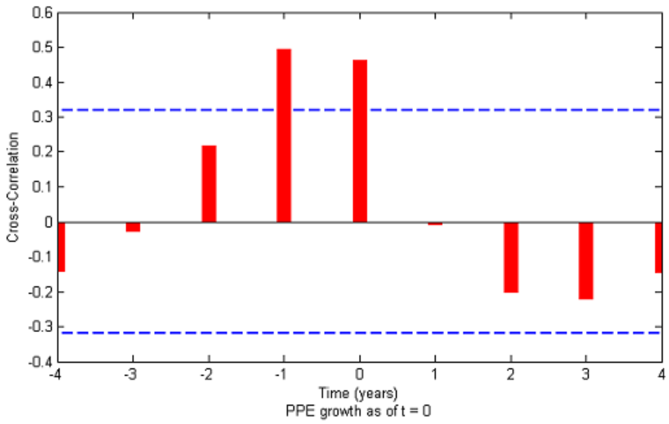


Figure 5: (Continued)

Panel C: Median Fixed Capital Growth (t=0) and Employee Growth ($t-3$, ..., $t+3$)



A number of papers in economics model inventories as a factor of production, assuming positive substitutability between inventories and fixed capital (e.g., Kydland and Prescott (1982), Christiano (1988), Ramey (1989)). The inventory-for-capital substitution is not unintuitive. For example, by increasing input materials, firms can make a relatively large production run at a time thereby reducing the average downtime (idle time between batches). Similarly, when retailers see the increase in demand, they can respond to the demand shocks by ordering, storing and shelving more goods, yet not immediately building a new store. Adjusting inventories is presumably less costly than adjusting fixed capital. For example, changing the purchase-order quantities of input materials may incur costs associated with re-stocking and storing them, but these costs are much more affordable than those associated with installing and disposing of machines or structures. These types of adjustments in fixed capital involve a learning process, interference with all or part of the production line, fire sales, and so on.

In sum, inventories' strong procyclicality, tendency to precede fixed capital adjustment, productive roles played, and relatively low adjustment costs all suggest that inventories fit well the definition of variable capital.

APPENDIX B

NUMERICAL SOLUTION PROCEDURE

To solve the model numerically, I use the value function iteration method to solve the firm's dynamic optimization problem. The value function and the optimal decision rules are solved on a grid in a discrete state space. The construction of the grids for fixed capital K and inventories N follows the recursive method of McGrattan (1999), that is, $K_i = K_{i-1} + c_1 \exp\left[c_2 \left(i - 2\right)\right]$, where $i = 1, \ldots, n$ is the index of grid points and c_1 and c_2 are two constants chosen to provide the desired number of grid points and upper bound K_{max}, given a pre-specified lower bound K_{min}. The advantage of this recursive construction is that more grid points are assigned around the lower bound, where the value function has most of its curvature. I build a grid in which the number of points is 56 in each dimension, K and N, and the upper bounds K_{max} and N_{max} are large enough to be non-binding at all times.

To transform the productivity state X into a discrete state space, I use a nine-state Markov process. The popular method of Tauchen and Hussey (1991) is known to work not well when the persistence of AR(1) process is above 0.9. Because the persistence ρ_x exceeds 0.9 at quarterly frequency, I use the method described in Rouwenhorst (1995) for a quadrature of the Gaussian shocks.[28]

Once the discrete state space is available, the conditional expectation operator in equation (8) can be carried out as a matrix multiplication. The results are robust to the finer grids for the state variables.

[28] I thank Lu Zhang for providing on his website the Matlab code for the implementation of Rouwenhorst's method.

APPENDIX C

SIMULATION DETAILS

For each set of parameters as specified in the main text, I simulate 2000 firms over 1600 quarters (400 years) and drop the first 200 years to get rid of the effect of initial values of the state variables. Using the numerical solutions (i.e., the optimal investment policies regarding inventories and fixed capital and the corresponding firm values), I generate the variables of interest, including fixed capital, inventory stocks, operating profits, and investments. Then, the quarterly quantity variables are aggregated to an annual frequency to perform a series of tests outlined in the main text.

APPENDIX D

EMPIRICAL SAMPLE AND VARIABLES

The empirical sample consists of the U.S. manufacturing firms (SIC code 2000-3999) from the Compustat annual file for the period of 1971-2009 that satisfy the following common data-screening requirements in the literature (e.g., Almeida, Campello, and Weisbach (2004)): book assets greater than 10 million in \$2008; firm age (Compustat appearance) of at least three years; book equity and market equity greater than zero; cash, inventories and PPE capital less than book assets; the presence of inventory data; the ratios of $\frac{\text{book assets}_t}{\text{book assets}_{t-1}}$ and $\frac{\text{sales}_t}{\text{sales}_{t-1}}$, respectively, between 0.5 and 2 (to eliminate the candidates that are likely to have gone through significant reorganization such as mergers and acquisitions and spin-offs); and the firms' appearance in consecutive fiscal years. For the use of the CRSP monthly stock return file, the following requirements are added: common stocks (share code 10, 11 and 12) with a price greater than \$1 and at least ten valid observations of monthly returns for the annual return calculations for a given fiscal year. I find that all results are robust to a number of alternative screening procedures, which include alternative SIC filtering to cover all non-financial and non-utility firms (i.e., remove SIC codes 6000-6999 and 4900-4999), elimination of negative cash-flow observations, and an increase or decrease in the cutoff values for book-asset firm size.

Details of the variable definition are found below. The description of variables specifically used in Section 3.3 appears in the main text therein. All variables, after the described sample screening and appropriate normalization, are winsorized at 1% in both tails by fiscal year.

- Tobin's Q is market value divided by book value (book assets (AT)), where market value equals book assets minus book common equity minus deferred tax and investment credit plus market equity (AT – CEQ – TXDITC + PRCC_f * CSHO). If CEQ is not available from the Compustat, then book common equity is stockholders'equity (SEQ) minus preferred stock, where preferred stock is either the Compustat item PSTKRV, PSTKL or PSTK, in that order, as available.

- K (fixed capital) is property, plant and equipment (PPENT/AT).
- N (inventories) is inventories (INVT/AT).
- *Cash* is cash holdings (CHE/AT).
- CF (cash flows) is net income plus depreciation ((NI$_t$ + DEPR$_t$)/AT$_{t-1}$).
- I^k (fixed capital investment) is capital expenditure minus sale of PPE capital ((CAPX$_t$ – SPPE$_t$)/AT$_{t-1}$).
- ΔN (inventory adjustment) is changes in inventories ((INVT$_t$ – INVT$_{t-1}$)/AT$_{t-1}$).
- SD[N/K] is the firm-level time-series standard deviation of N/K ratio. For the baseline inventory-capital substitution measure, standard deviation of ln(N/K) is calculated as described in the main text.
- CORR[g^N, g^K] is the firm-level time-series correlation between inventory growth and fixed capital growth.
- *Debt Issue* is long-term debt issues less retirement (DLTIS$_t$/AT$_{t-1}$).

- *Equity Issue* is equity issues less repurchases ($\text{SSTK}_t/\text{AT}_{t-1}$).

- SA index is Size-Age financing constraint index (Hadlock and Pierce (2010)), calculated as

$$\text{SA index} = -0.737(\text{Size}) + 0.043(\text{Size}^2) - 0.040(\text{Age}),$$

  where Size is the log of inflation adjusted ($2008) book assets, and Age is the number of years the firm has been on Compustat. Further, Size is replaced with log of $4500 million and Age with 37 years if the actual values exceed these thresholds. For inflation-adjustment, Consumer Price Index for All Urban Consumers (CPIAUCSL) is used.

- KZ index is Kaplan-Zingales financing constraint index (Lamont, Polk and Saa-requejo (2001)), calculated as

$$\begin{aligned}\text{KZ index} &= -1.002(CF/K) + 0.283(Q) + 3.139(Debt/TotalCapital) \\ &\quad - 39.368(Div/K) - 1.315(Cash/K),\end{aligned}$$

  where *CF* is net income plus depreciation, Q is Tobin's Q, and K is PPE capital.

- Altman's Z-score is the measure of the firm's financial distress, calculated as

$$\begin{aligned}\text{Z-score} &= 1.2(\text{WC/AT}) + 1.4(\text{RE/AT}) + 3.3(\text{EBIT/AT}) \\ &\quad + 0.6(\text{ME/BL}) + 0.999(\text{SALE/AT}),\end{aligned}$$

  where WC is working capital (WCAP), RE retained earnings (RE), EBIT earnings before interests and taxes (OIADP), ME market value of equity, and BL book liabilities (LT).