Inventory Behavior and Financial Constraints: Theory and Evidence *

Sudipto Dasgupta, † Erica X.N. Li‡ and Dong Yan §

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Abstract

In this paper, we develop a theoretical model that studies the interaction of financial constraints and inventory behavior. The main intuition we try to model is that firms' incentives to build inventory when production costs are low and deplete inventory when costs are high are exacerbated when they face financial constraints and have difficulty in rebuilding capital. The model provides a number of insights on the determinants of inventory holdings in the presence of financial constraints. Using model-generated data, we develop several empirical tests of the theory. These tests have the advantage that we do not need to interpret coefficients of cash flows in our regressions, which has been controversial due to measurement error issues. When we take these tests to the actual data, we find very consistent results.

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Keywords: inventory, financial constraints, capital investments

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†Department of Finance, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; Tel: (852) 23587685; E-mail: dasgupta@ust.hk.

‡Department of Finance, Cheung Kong Graduate School of Business, Beijing, China, 100738; Tel: (86)10 85188888 exit 3075; E-mail: xnli@ckgsb.edu.cn.

§Department of Finance, Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong; Tel: (852) 62340862; E-mail: dyan@ust.hk.

1 Introduction

The determinants of firms' inventory holding behavior, and in particular, how financial constraints are likely to affect inventory holdings, have not received the same attention in the Finance literature as, for example, firms' cash holding behavior. While *change* in inventory holdings constitutes less than 1 percent of GDP in advanced countries, it has long been recognized that inventory holdings play an important role in aggregate output fluctuations [1]. Further, the level of inventory holdings for corporations is substantial: 30 percent of lagged capital [2], compared to 15 percent of lagged capital for corporate cash holdings.

Two of the earliest studies of the financial determinants of inventory holdings (Kashyap, Stein and Wilcox (1993) and Kashyap, Lamont and Stein (1994)) attempted to resolve the puzzling lack of evidence that the cost of finance (or the cost of carry for inventory) affects inventory behavior. Both papers found evidence that in recent U.S. recessions, a so-called "bank-lending channel" seemed to have affected the ability of bank-dependent and liquidity constrained firms to invest in inventory. Subsequently, Carpenter, Fazzari and Petersen (1994) (hereinafter CFP), using quarterly data from *Compustat*, demonstrated that during three sub-periods from 1981-1992 when monetary policy had a different stance in the U.S. and an inventory cycle was generated, corporate cash flows affected inventory behavior, and more so for financially constrained firms (smaller firms) than for unconstrained firms (larger firms). CFP interpreted this evidence as consistent with the idea that, when faced with a liquidity shortage, financially constrained firms are more likely to cut inventory investment than other types of investment (for example, investment in fixed assets or in R&D) which are associated with larger adjustment costs (that is, are less flexible).

In this paper, we present a model of inventory behavior in which production capacity, sales,

[1] An often-cited finding reported in Blinder and Maccini (1991) is that in postwar U.S. recessions, decline in inventory investment accounts for 87 percent of the total peak-to-trough movement in GDP. Ramey and West (1999) confirm the importance of inventory fluctuations in recent recessions for G7 countries.

[2] Throughout the paper, "capital" stands for book value of assets less inventory, for reasons that will be discussed later.

and inventory holding decisions are simultaneously made by financially unconstrained as well as constrained firms. We calibrate the model to replicate observed differences in first and second moments of sales and inventory holdings (scaled by lagged capital) as well as changes in inventory, sales and capital (also scaled by lagged capital) between financially unconstrained and financially constrained firms. In particular, our model calibrations generate similar differences in the ratio of inventory holdings to lagged capital for constrained and unconstrained firms as in the actual data (median values of 16 and 22 percent, respectively, for financially unconstrained and constrained firms for the model generated data versus 14 and 19 percent in the *Compustat* data at quarterly frequency). Based on our model, we then derive a key empirical implication of financially constrained behavior, test this implication on model-generated data, and then take the same test to the real data. We find very consistent results. An important feature of this test is that, unlike most other tests of financially constrained behavior, we do not need to rely on cash flow sensitivities to interpret our results.

Our model builds on the notion that capital investment is not only associated with higher adjustment costs relative to inventory, but for financially constrained firms, capital is also difficult to rebuild. The main building blocks of our inventory model are traditional. We use a variant of the standard "linear-quadratic" model [3], and allow a role for both cost and demand shocks, although the former play a more important role in our calibrated model. This latter feature is consistent with the widely documented fact that inventory movements are procyclical. In these linear-quadratic models, persistent shocks to both cost and demand are the main drivers of inventory behavior. However, in reality, investment in capital and capacity constraints are also likely to play an important role, especially for financially constrained firms. When shocks to marginal cost of production are present, given negatively sloped demand and marginal revenue, firms have an incentive to produce more than the quantity that equates marginal revenue and marginal

[3] See, for example, Ramey and West (1999), section 3. CFP (1994) provide an excellent overview of the literature, including prior work on the effect of monetary policy on inventory holdings.

cost when the marginal cost curve is lower, and carry inventory to periods when the marginal cost curve is higher, in order to equalize marginal cost of production across periods. In other words, firms will attempt to produce more than they would sell in good cost states, and sell from inventory in bad cost states [4]. The optimal level of inventory holdings will trade off the benefits of production cost smoothing with the cost of holding inventory. Such smoothing of production costs (or, equivalently, of sales) is likely to be more important for financially constrained firms for two reasons. First, financially constrained firms may have to cut investment or divest assets in bad cost states (when profits are low) to cover operating costs because they are unable to access external finance, and capital is difficult to rebuild for such firms even under better times. Second, investment adjustment costs not only limit the ability to cut investment when profits are low, they also make it more costly to rebuild capital. For both these reasons, selling from inventory is more attractive in bad cost states, which implies that it is more important to accumulate inventory when costs are more favorable. In effect, financially constrained firms are willing to engage in more complete production cost smoothing behavior and pay the cost of holding inventory when they can afford to do so, in return for more sales revenue in bad cost states, which allows them to avoid costly capital adjustment [5].

As noted above, unconstrained firms also have incentives to smooth sales by building inventory

[4] For manufacturing firms, cost shocks can originate in shocks to input prices, e.g. prices of energy inputs, productivity shocks to input suppliers, or exchange rate fluctuations. An extensive literature documents the importance of input price shocks for aggregate economic fluctuations (see, for example, Bruno and Sachs (1982)). Eichenbaum (1989) finds evidence consistent with production-cost smoothing and the importance of cost shocks for inventory behavior. Blanchard (1983), Durlauf and Maccini (1995), Ramey (1989) and West (1986) all emphasize the importance of cost shocks for inventory behavior. A recent paper by Wang and Wen (2011) develops a General Equilibrium model based on production-cost smoothing behavior that is consistent with many stylized facts regarding aggregate inventory fluctuations.

[5] We do not model cash holdings, primarily because it is difficult to argue why financially unconstrained firms should hold cash. However, as our model shows, pure smoothing incentives can lead to inventory holdings by unconstrained firms even when they have no motive for holding cash. For constrained firms, the smoothing incentives are exacerbated by the presence of financial constraints. In Appendix A, we show that as long as there is some cost to cash holdings, constrained firms hold more (less) inventory than unconstrained firms in relatively good (bad) cost states. Costs to holding cash are typically assumed in dynamic models of cash holding behavior – for example, Riddick and Whited (2009) assume that because interest on cash holdings is taxed, there is a tax penalty to cash holdings. Bolton, Chen and Wang (2011) also assume a carry cost for cash holdings.

in favorable cost states and depleting inventory in unfavorable cost states . However, a key implications of the model is that relative sensitivity of the inventory response by unconstrained firms vis-a-vis the constrained firms to favorable and unfavorable shocks will be asymmetric. Capacity constraints play a more important role for the difference in the response on the upside, that is, when the cost shock is favorable. Not only do unconstrained firms have more (physical) capital than constrained firms, because they have better access to external finance, they are also able to adjust capital immediately in response to shocks. Thus, inventory and capital start to build up immediately after favorable cost shocks. In contrast, financially constrained firms are able to build up capital and inventory less rapidly, as profitability improves in response to a persistent favorable shock. Eventually, however, as the good state persists, they accumulate significant inventory. On the other hand, when the cost shock is adverse, as discussed above, constrained firms have a stronger incentive to liquidate inventory than do unconstrained firms.

We first demonstrate the validity of these implications in our calibrated model via regressions of inventory and capital growth on the shocks [6] as well as lagged state variables (i.e., lagged demand and cost realizations) to capture the effects of unexpected shocks. Next, because we do not try to measure the shocks in the real data, and use sales growth to proxy for these shocks, we show that in the model, the shocks to cost and demand translate to change in sales or "sales shocks", again by way of regressing sales growth on the shocks. Finally, we run similar regressions of change in inventory on sales growth in the model-generated data and the actual data, and find very consistent evidence in favor of asymmetric response. In particular, when sales growth is positive, in both the model data and the actual data, while both types of firms increase inventory growth in response to higher sales growth, the effect is more muted for constrained firms. When sales growth is negative, both types of firms reduce inventory, but the effect is stronger for constrained firms. We find similar results for capital growth. We also run the same tests using lagged sales growth instead of contemporaneous sales growth to address potential endogeneity arising out of

[6] Here, a "shock" represents a change in the level of the random component of cost or demand.

the fact that inventory and sales decisions are jointly made conditional on the state, and find very similar results. In the regressions where sales growth (or lagged sales growth) proxies for shocks to cost and demand, we control of cash flows at one period lag to sales growth, which we find in our simulated data to be highly correlated with the demand and cost states and hence are intended to control for anticipated sales growth.

The issue of whether information asymmetry vis-a-vis financial markets constrains certain types of firms from raising external capital, and thus affects real activity in the economy, has been a difficult one to resolve empirically. Most approaches have attempted to examine this question by appealing to the notion that in the presence of information asymmetry, internal funds are less expensive than external funds.[7] Thus, one empirical strategy has been to examine whether internal cash flows positively affect investment levels, after controlling for Tobin's Q in the neoclassical investment regression. This approach, however, has been criticized on the ground that the empirical proxy for Q is measured with error, and therefore, cash flow may contain information about investment opportunities[8]. Other approaches, such as examining whether or not firms more likely to be financially constrained hold more cash (when they enjoy higher cash flows) to mitigate the effects of future financial constraints [9], have also been criticized on similar grounds.

Importantly, for our empirical tests, while we do include lagged cash flows in our regressions to control for the unobserved "state" of demand or cost, we do not attempt to interpret the coefficients of cash flows. Our tests also do not incorporate market value-based measures such as Tobin's Q. In this regard, our approach is similar to that in a recent paper by Gala and Gomes (2013). These authors argue that sales and cash flows contain information about state variables that affect future returns to investment, and demonstrate that simple polynomial representations of an investment equation involving quadratic and interaction terms involving firm size and sales

[7]See, for example, pioneering papers by Fazzari, Hubbard and Petersen (1988), Hoshi, Kashyap and Scharfstein (1991).

[8]See Erickson and Whited (2000), Alti (2003), Gomes (2001), and Moyen (2004).

[9]see Almeida, Campello and Weisbach (2004).

over assets explain a much higher percentage of the within-variation and the explained variation in investment than does a Tobin's Q-based model.

Our model is perhaps most directly relevant for finished goods inventories of manufacturing firms. A limitation of quarterly data from *Compustat* is that we do not get disaggregated inventory data at that frequency earlier than the year 2000. However, in the inventory literature, several authors have argued that intermediate goods inventories are similar to factors of production like capital [10]. In particular, if raw material inventory is held in fixed proportion to capital, it is possible to interpret firms' capital investment response to shocks as representative of the response of intermediate goods inventory. For our model-generated data, capital investment responds to shocks in a similar way to inventory. Moreover, the "invisible hand" argument (Blanchard (1983)) suggests that if costs shocks are common across producers and users of intermediate goods, then intermediate goods will be accumulated precisely when their producers have excess inventories, and they will be more expensive when producers produce less as costs go up. Thus, investment in intermediate goods should also be procyclical, and constrained firms may have a stronger incentive to cut investment in intermediate goods inventory in bad times (and therefore buffer up in good times).

On average, constrained firms carry more inventory (both in reality as well as in our model-generated data) than do unconstrained firms. Our model provides insights as to which factors are important in affecting the inventory holding behavior for these two types of firms. A key factor is the quadratic accelerator term that embodies inventory holding and backlog (stock-out) costs [11]. When the costs associated with deviations of inventory from sales decrease, unconstrained firms

[10]See Ramey (1989), and also section 3.4 in Ramey and West (1999). Two recent papers model inventory as a factor of production together with capital. Jones and Tuzel (2012) study the effects of cost of capital on inventory investment and find that risk premium is negatively related to future inventory growth. They use risk premium to proxy for financial conditions and find consistent results with previous literature. Belo and Lin (2012) model inventory the same way as Jones and Tuzel (2012), but study the relation between stock returns and inventory growth rate. They find that firms with lower inventory growth rate outperforms firms with higher inventory growth rate. Inventory adjustment costs are important in these models in explaining the return spreads between high and low inventory growth firms, following standard q-theory logic.

[11]See Ramey and West (1999) for the interpretation and microfoundations for this term.

hold significantly lower inventory as a fraction of assets, whereas the opposite is true for constrained firms. This suggests that uncosntrained firms are penalized more for stockout (that is, not having enough inventory to satisfy demand), while constrained firms are penalized more for holding excess inventory. Fixed operating costs have no effect on either invested capital or inventory holdings of unconstrained firms, but higher values lower invested capital and raise inventory holdings of constrained firms (so that the ratio of inventory holding to capital increases and is highly sensitive to this parameter). Lower investment adjustment costs increase the average level of invested capital by both types of firms [12], and the level of inventory holdings also increases (because production is higher with more capital). However, for constrained firms, the investment effect dominates, so investment inflexibility tends to push up the ratio of inventory to capital more for constrained firms. Importantly, steeper marginal cost and demand curves increase the inventory levels of constrained firms as they create more incentives for smoothing behavior, although they reduce capital. Thus, there is a substantial effect on the ratio of inventory to capital for such firms, while there is a much smaller effect on the inventory-to-capital ratio for unconstrained firms. Similarly, both cost and demand volatility, but especially the former, have a much stronger positive effect of the inventory-to-capital ratio of the constrained firms.

In summary, we make four major contributions in this paper. The first is to explicitly model capital accumulation, and the interaction between production capacity and inventory accumulation, previously unmodelled in the literature. The second is to model and examine the effect of financial constraints on this interaction. Similar to the informal arguments in CFP, our model captures the idea that when faced with poor profitability, financially constrained firms without access to external financial markets may prefer to liquidate inventory rather than capital. While CFP test their hypothesis in terms of cash flow coefficients, we derive and test a different implication which does not require us to rely on the interpretation of cash flow coefficients, an issue

[12] Since capital has to be committed in advance of production, even unconstrained firms can be capacity constrained and lose profits. If capital is more flexible, given volatility of cost and demand shocks, firms are more willing to invest.

that has been the subject of much debate in recent literature. Herein lies our third contribution. Finally, we attempt to isolate several factors that affect inventory holding behavior both in the presence and absence of financial constraints, and in the process, suggest possible reasons for the much higher inventory holdings of constrained firms. This is an issue that, unlike cash holdings, has been completely untouched in recent literature, and could potentially be tested with suitable firm-level constructs.

The paper is organized as follows. Section 2 introduces the model and explores the implications. Sections 3 and 4 explain the data sample and the calibration of the model, respectively. Section 5 shows our empirical findings. Section 6 concludes.

2 The Model

Production function. – Assume Cobb-Douglas production function:

$$Y_t = e^{X_t}\left(1 - \frac{hS_t}{A_t}\right)S_t \tag{1}$$

$$Q_t \leq A_0 A_t^{1-\alpha} K_{t-1}^{\alpha} \tag{2}$$

where Y_t is the sales measured in dollars, X_t is the demand shock, h is a constant referring to the slope of the demand curve, S_t is the sales measured in quantity, Q_t is the output level, K_{t-1} is the capacity/capital at the beginning of period t, and α is the capital to output ratios, and $A_0 A_t$ is the productivity level with A_0 being a constant scaling factor. Assume that the demand shock follows an AR(1) process

$$X_{it+1} = \bar{X} + \rho_X \left(X_{it} - \bar{X}\right) + \varepsilon_{it+1}^X ,$$

where ε_{it+1}^X is an i.i.d. process with standard deviation of σ_x. For any pair (i, j) with $i \neq j$, ε_{it+1}^Z and ε_{jt+1}^Z are uncorrelated. $\bar{X}$ is the long-run average of the demand shock and is a scaling factor in the model. To isolate the effects of demand shocks and for simplicity, we assume that productivity level A_t grows at a constant rate g, i.e.,

$$A_t = g^t \, .$$

The appearance of A_t in the demand curve is to ensure balanced growth.

Production costs. – Production costs include time-varying linear costs and quadratic costs:

$$C_{Qt} = e^{Z_t} \left[d_1 Q_t + \frac{d_2}{2A_t} Q_t^2 \right] \, , \tag{3}$$

where Z_{it} is the cost shock, d_1 and d_2 are constants, and Q_t is the output level at time t. The productivity level A_t appears in the quadratic term to ensure balanced growth. To generate panel data, we assume that the cost shock z_{it} for firm i is firm-specific and is uncorrelated across firms. The cost shocks have a common stationary and monotone Markov transition function, $Q_Z(Z_{it+1}|Z_{it})$, given by:

$$Z_{it+1} = \rho_Z Z_{it} + \sigma_z \varepsilon^Z_{it+1}, \tag{4}$$

where ρ_Z is the autocorrelation coefficient and ε^Z_{it+1} is an i.i.d. standard normal variable. For any pair (i, j) with $i \neq j$, ε^Z_{it+1} and ε^Z_{jt+1} are uncorrelated. Moreover, ε^X_{it+1} is independent of ε^Z_{it+1} for all i.

Inventory stockout avoidance costs. – Following Blanchard (1983), we assume a quadratic stockout avoidance costs for inventory holdings, i.e.,

$$C_{Nt} = \frac{b}{2} \left(\frac{S_t}{A_t} \right)^{\gamma} \left(1 - \frac{c\, N_t}{S_t} \right)^2 \, , \tag{5}$$

where N_t is the inventory level and γ measures the elasticity of the stockout avoidance costs to sales. Constant b measures the magnitude of the stockout costs and c refers to the sales-to-inventory ratio that results in zero stockout costs. Again, we include A_t in the cost function to ensure balanced growth. The underlying justification for the stockout avoidance costs is that this cost function is itself the sum of two cost functions: the first is the physical cost of carrying inventories, which is an increasing function of the level of inventories; the second is the expected cost of stocking out, which is a decreasing function of the level of inventories given sales, as a higher inventory- to-sales ratio decreases the probability of stocking out. The sum of these two costs reaches a minimum for some level of inventories.

Capital accumulation. – The law of capital accumulation follows

$$K_t = (1-\delta)K_{t-1} + I_t \,,$$

where δ is the depreciation rate and I_t is the investment made at time t.

Investment adjustment costs. – We assume quadratic adjustment costs:

$$C_{It} = \frac{a}{2}\left(\frac{I_t}{K_{t-1}}\right)^2 K_{t-1} \,,$$

where a is a positive constant.

Operating costs. – Assume that the operating costs include both fixed and variable costs, where the latter depends on the production capacity. By introducing the variable costs of capacity, firms will also have the incentive to decrease capacity during bad times.

$$C_{Ot} = A_t \left[f_0 + f_1\left(\frac{K_{t-1}}{A_{t-1}}\right)\right] \,,$$

where f_0 and f_1 are constants and the appearance of A_{t-1} is to ensure balanced growth.

Dividend payout. — The dividend of the firm at time t is then given by

$$D_t = Y_t - C_{Ot} - C_{Qt} - C_{Nt} - C_{It} - I_t \,.$$

Value maximization. – For simplicity, we assume that the firm is an all-equity firm and there is no agency problems. The optimal firm value is given by the following optimization problem:

$$V_t(K_{t-1}, N_{t-1}, X_t, Z_t) = \max_{\{Q_t, N_t, I_t\}} \{D_t + \mathbb{E}_t[M_{t+1}V_{t+1}]\} ,$$

where M_{t+1} is the stochastic pricing kernel and the maximization is subject to the following constraint

$$Q_t = S_t + N_t - N_{t-1} .$$

For simplicity, we solve the model for two types of firms: (1) financially unconstrained firms who can seek external financing with no costs; (2) financially constrained firms whose dividend has to be nonnegative, i.e., $D_t \geq 0$. The model is solved using second-order perturbation method, which requires that the objective function is differentiable and unconstrained.[13] For constrained firm, the optimization problem can be approximated by the following

$$\hat{V}_t(K_{t-1}, N_{t-1}, X_t, Z_t) = \max_{\{Q_t, N_t, I_t\}} \left\{ D_t + \mathbb{E}_t\left[M_{t+1}\hat{V}_{t+1}\right] + \left(\frac{A_t}{\varpi_1}\right) \log\left(\frac{D_t}{A_t}\right) \right\} ,$$

where the last term drops to negative infinity rapidly as D_t is close to zero and is called logarithmic barrier. As ϖ increases to ∞, the above optimization problem converges to our original optimization problem.

[13]The value function iteration method is not subjected to this constraint however it suffers from the curse of dimensionality. Given that our model has four state variable ($\{K_{t-1}, N_{t-1}, X_t, Z_t\}$ and three independent endogenous variables $\{Q_t, N_t, I_t\}$, the value function iteration method is not applicable.

To add the constraints that output cannot exceed the capacity, we follow the same strategy, i.e.,

$$
\begin{aligned}
\hat{V}_t(K_{t-1}, N_{t-1}, X_t, Z_t) &= \max_{\{Q_t, N_t, I_t\}} \left\{ D_t + \mathbb{E}_t \left[M_{t+1} \hat{V}_{t+1} \right] \right. \\
&\left. + \left(\frac{A_t}{\varpi_1} \right) \log \left(\frac{D_t}{A_t} \right) + \left(\frac{A_t}{\varpi_2} \right) \log \left[A_0 \left(\frac{K_{t-1}}{A_t} \right)^{\alpha} - \left(\frac{Q_t}{A_t} \right) \right] \right\},
\end{aligned}
$$

It can be easily shown that firm value V_t, capital level K_t, sales S_t, inventory N_t, all the costs C_{Qt}, C_{Ot}, and C_{It}, and dividend D_t all grows at the same rate as A_t. Define the scaled variables as

$$
\tilde{K}_t = \frac{K_t}{A_t} \quad \tilde{I}_t = \frac{I_t}{A_t} \quad \tilde{D}_t = \frac{D_t}{A_t} \quad \tilde{C}_{Q,t} = \frac{C_{Q,t}}{A_t} \quad \tilde{C}_{N,t} = \frac{C_{N,t}}{A_t} \quad \tilde{C}_{I,t} = \frac{C_{I,t}}{A_t} \quad \tilde{C}_{O,t} = \frac{C_{O,t}}{A_t}
$$

$$
\tilde{V}_t = \frac{V_t}{A_t} \quad \tilde{Q}_t = \frac{Q_t}{A_t} \quad \tilde{S}_t = \frac{S_t}{A_t} \quad \tilde{N}_t = \frac{N_t}{A_t}.
$$

All scaled variables have a stationary distribution. For financially constrained firms, the first order conditions w.r.t. $\tilde{N}_t$, $\tilde{Q}_t$ and $\tilde{I}_t$ using scaled variables are given by

$$
\tilde{N}_t : \quad \left(1 + \frac{1}{\varpi_1 \tilde{D}_t} \right) \left[e^{X_t} - H_t \right] = \beta \mathbb{E}_t \left\{ \left(1 + \frac{1}{\varpi_1 \tilde{D}_{t+1}} \right) \left[e^{X_{t+1}} - G_{t+1} \right] \right\} \tag{6}
$$

$$
\tilde{Q}_t : \quad \left(1 + \frac{1}{\varpi_1 \tilde{D}_t} \right) \left[e^{X_t} - e^{Z_t} \left(d_1 + d_2 \tilde{Q}_t \right) - G_t \right] = \frac{1}{\left[\varpi_2 \left(A_0 \tilde{K}_{t-1}^{\alpha} g^{-\alpha} - \tilde{Q}_t \right) \right]} \tag{7}
$$

$$
\begin{aligned}
\tilde{I}_t : \quad & \left(1 + \frac{1}{\varpi_1 \tilde{D}_t} \right) \left[1 + a g \left(\frac{\tilde{I}_t}{\tilde{K}_{t-1}} \right) \right] = \mathbb{E}_t \left\{ M_{t+1} g \left(1 + \frac{1}{\varpi_1 \tilde{D}_{t+1}} \right) \right. \\
& \times \left[\frac{a}{2} g \left(\frac{\tilde{I}_{t+1}}{\tilde{K}_t} \right)^2 - f_1 + (1 - \delta) g^{-1} \left(1 + a g \left(\frac{\tilde{I}_{t+1}}{\tilde{K}_t} \right) \right) \right] \\
& \left. + M_{t+1} g \left[\frac{\alpha \tilde{K}_t^{\alpha - 1} g^{-\alpha}}{\varpi_2 \left(A_0 \tilde{K}_t^{\alpha} g^{-\alpha} - \tilde{Q}_{t+1} \right)} \right] \right\},
\end{aligned} \tag{8}
$$

where

$$H_t = \frac{b\gamma}{2}\tilde{S}_t^{\gamma-1}\left(1-\frac{c\tilde{N}_t}{\tilde{S}_t}\right)^2 + bc\tilde{S}_t^{\gamma-2}(\tilde{N}_t+\tilde{S}_t)\left(1-\frac{c\tilde{N}_t}{\tilde{S}_t}\right)$$

$$G_t = \frac{b\gamma}{2}\tilde{S}_t^{\gamma-1}\left(1-\frac{c\tilde{N}_t}{\tilde{S}_t}\right)^2 + bc\tilde{S}_t^{\gamma-2}\tilde{N}_t\left(1-\frac{c\tilde{N}_t}{\tilde{S}_t}\right).$$

For financially unconstrained firms, let $\varpi_1 \to \infty$ and we get

$$\tilde{N}_t: \quad \left[e^{X_t} - H_t\right] = \beta\mathbb{E}_t\left\{\left[e^{X_{t+1}} - G_{t+1}\right]\right\} \tag{9}$$

$$\tilde{Q}_t: \quad \left[e^{X_t} - e^{Z_t}\left(d_1 + d_2\tilde{Q}_t\right) - G_t\right] = \frac{1}{\left[\varpi_2\left(A_0\tilde{K}_{t-1}^{\alpha}g^{-\alpha} - \tilde{Q}_t\right)\right]} \tag{10}$$

$$\begin{aligned}\tilde{I}_t: \quad \left[1 + ag\left(\frac{\tilde{I}_t}{\tilde{K}_t}\right)\right] &= \beta\mathbb{E}_t\{\, g \times \left[\frac{a}{2}g\left(\frac{\tilde{I}_{t+1}}{\tilde{K}_t}\right)^2 - f_1\right.\\ &\left.+ (1-\delta)\, g^{-1}\left(1 + ag\left(\frac{\tilde{I}_{t+1}}{\tilde{K}_t}\right)\right)\right] + g\left[\frac{\alpha\tilde{K}_t^{\alpha-1}g^{-\alpha}}{\varpi_2\left(A_0\tilde{K}_t^{\alpha}g^{-\alpha} - \tilde{Q}_{t+1}\right)}\right]\Bigg\}.\end{aligned} \tag{11}$$

For simplicity, we assume that the stochastic discount factor is a constant β. Based on the above first order conditions, we solve for the optimal production, inventory holding, and investment for financially unconstrained firms and constrained firms, respectively.

3 Data

Our data sample consists of firms listed in the *Compustat* Industrial Quarterly Files at any point between 1971 and 2010. Following standard practice, we exclude financial, insurance, and real estate firms (SIC code 6000-6900), and utilities (SIC code 4900-4999). We exclude from the sample any firm-quarter observation that has missing book value of asset, sales or inventory. We also restrict the sample to firms with at least five consecutive years of data. All dollar values are converted into 2000 constant dollars. Firm characteristics, such as sales (scaled by lagged capital) and inventory (scaled by lagged capital) are winsorized at 1% level at both tails of the distribution to alleviate the impact of outliers. In addition, following CFP, we drop firms with total asset less than 15.5 million (in 2000 constant dollars). The final dataset is an unbalanced panel consisting of 285,075 firm-quarter observations.

3.1 Variables

Inventory in our study is given by *Compustat* data item INVTQ, which includes raw materials, finished goods, work-in-progress and other inventory. Ideally, we would like to use each of these components separately for our empirical study. Unfortunately, inventory components for quarterly data are missing for all the firms until 2000. Even in year 2010, 30% of the firms do not have inventory components data on quarterly frequency. To correct the bias that inventory stock value is understated under LIFO and overstated under FIFO, following CFP, we apply an algorithm developed by Michael Salinger and Lawrence Summers to adjust for LIFO (last in, first out) and FIFO (first in, first out) accounting. [14]

Capital is defined as total asset minus inventory. This is because capital stock in the model does not include inventory. [15] Sales in actual data is the level of net sales (SALEQ). Cash Flow is calculated as the sum of earnings before extraordinary items (IBQ) and depreciation (DPQ) scaled by lag capital. Quarterly Capital Expenditure is calculated by converting the *Compustat* Year-To-Date item CAPXY to quarterly frequency.

Ratios including $Invt_t/K_{t-1}$, $Sales_t/K_{t-1}$, $Capex_t/K_{t-1}$ and CF_t/K_{t-1} are all scaled by lagged capital. $CapitalGrowth$, $InvtGrowth$, $SalesGrowth$ and $PPEGrowth$ are defined as change in

[14] For more detailed description of the adjustment method, please refer to Salinger and Summers (1983) and the appendix of Carpenter, Fazzari and Petersen (1994). Our results are robust if we do not adjust for FIFO and LIFO.

[15] All our results are robust if we use total asset as capital.

the levels of capital, inventory, sales and property plant and equipment (PPENTQ) (in 2000 constant dollars) from year t to year t-1, scaled by capital in year t -1.

We use the reported fiscal quarter end to align fiscal quarters with calendar quarters. Following CFP and Carpenter, Fazzari and Petersen (1998), in cases where the end of fiscal quarter does not coincide with the end of a calendar quarter, we adjust the data so that the majority of the fiscal quarter is assigned to the appropriate calendar quarter.

3.2 Financially Constrained Firms

Following CFP, we use firm size as the basis for classification schemes for the financial constraint status. In each quarter, we rank firms according to the book value of asset at the beginning of the period and assign the top 30% to the financially unconstrained group (UFC), while the bottom 30% to the financially constrained group (FC). Thus, we allow the status to vary over time.

4 Calibration and Simulation

We calibrate the model at quarterly frequency. Table 1 presents the parameter values used in the calibration. Our calibration strategy is as follows. The capital-to-output ratio α is set to 0.7 to be consistent with the estimate in Hennessy and Whited (2007). The growth rate of productivity g is 1.009, chosen to match the average growth rate of sales in our sample. Since we assume risk-neutrality in the model, the discount rate is the risk-free rate, given by $\frac{1}{\beta g}$. The discount factor β is hence set to 0.982 to generate a quarterly interest rate of 0.91%. In equilibrium, the average investment-to-capital ratio is given by $1-(1-\delta)/g$ in the model. Capital depreciation rate δ is then chosen to match the quarterly investment-to-capital ratio of 0.024 in our sample period. Investment adjustment cost parameter a is chosen to match the volatility of investment-to-capital ratio. The slope of the demand curve h is chosen to generate an average markup of 20%, consistent with the calibration in Altig et al. (2011). The scaling factor A_0 in the capacity constraint is chosen to match the average capacity utilization rate of 80% for the sample period 1970 - 2010. [16] The stockout avoidance cost ratio c is set to 1.3 to match the mean of inventory-to-sales ratio. The remaining 11 parameters, long-run mean of demand $\bar{X}$, the stockout avoidance cost parameter b, elasticity of stockout-avoidance cost to sales γ, production cost parameters d_1 and d_2, the persistences and volatilities of demand shocks and costs shocks, ρ_d, σ_d, ρ_c, and σ_c, and the operating cost parameters f_0 and f_1, are chosen to match the means and volatilities of sales-to-capital ratio, inventory-to-capital ratio, sales change-to-capital ratio, inventory change-to-capital ratio, and cash flow-to-capital ratio and the volatility of inventory-to-sales ratio. In total, we have 19 parameters to match 19 moments in the data.

We simulate 100 panels, each with 1440 quarters and 600 firms, half of which are financially constrained and the other half are financially unconstrained. For each panel, the simulation starts from the steady state values of the state variables. We drop the first 720 quarters to ensure that the simulated economy has reached the equilibrium. The regressions are conducted for each simulated panel separately. The reported regression coefficients and the associated t-statistics are computed using the Fama-MacBeth method, i.e.,

$$\beta = \frac{1}{N}\sum_{i=1}^{N}\beta_i \qquad \sigma(\beta) = \sqrt{\sum_{i=1}^{N}\frac{(\beta_i-\beta)^2}{N}} \qquad t = \frac{\beta}{\sigma(\beta)/\sqrt{N}}\,,$$

where i refers to the i^{th} simulated panel.

[16] The capacity utilization data is from the IHS Global Insight dataset.

5 Empirical Results from Both Actual and Simulated Samples

5.1 Comparing Actual and Simulation Samples

Table 2 reports summary statistics for the actual and simulation samples. For all scaled variables (e.g. sales over capital or SalesGrowth), the simulation preserves the order of the first and second moments , i.e., in every case, if the mean or standard deviation is higher (lower) for unconstrained firms in comparison to constrained firms in the actual data, this is also the case in the simulated data.

It is important to emphasize that financially constrained and unconstrained firms differ in our model only in one dimension, namely, the degree of financial constraint. It is possible to argue, however, that these firms would differ in many other dimensions, which potentially could improve our calibration exercise. Hennessy and Whited (2007), for example, estimate parameters for small firms and large firms separately, and find that these firms differ in many dimensions. However, we choose not to go in that direction because we want to identify, as clearly as possible, the difference that financial constraints make to the inventory decisions of firms.

Table 3 presents correlations between variables in the simulated data. The main issue of interest here is to see how well the state variables (the random realizations of demand and cost) correlate with other firm variables that commonly feature in inventory studies. There are several noteworthy features. First, with one exception, the correlations are all positive (note that for cost, the correlations are with the negative of the cost realization, indicating a more favorable state). A better state of cost and demand is associated with higher sales over lagged capital, capital growth, inventory growth and sales growth, higher investment scaled by lagged capital, cash flow scaled by lagged capital, and capacity utilization. Second, consistent with the lower variance of demand realizations relative to cost realizations, the negative of the cost realization (higher values indicating more favorable states) is much more highly correlated with other firm variables than the demand realization. Third, demand realization has negligible correlation with inventory or inventory growth. This suggests that firms may accumulate inventory when they receive a positive demand shock because the demand shock is persistent (consistent with a production smoothing motive) but then rapidly deplete the inventory buffer to generate sales. In contrast, firms mainly accumulate inventory when the cost shock is favorable, consistent with sales smoothing, and stock up for bad times. Fourth, demand has a much higher correlation with sales than cost has – again, this is consistent with sales being sustained out of inventory when a positive demand shock hits, as opposed to sales being sacrificed in favor of inventory to some extent when a favorable cost shock hits. Fifth, even though demand is less volatile, favorable demand is highly profitable – the correlation of demand and cash flow is high. Firms boost sales when demand is favorable, which improves profitability.

The correlations among the remaining variables are consistent with expectations. One interesting set of comparisons between unconstrained and constrained firms involves capacity utilization. When unconstrained firms hit high utilization levels, they seem to be already holding close to desired inventory levels (the correlation with inventory over lagged capital is 0.92, but with inventory growth is 0.39). In contrast, constrained firms do not hold as much inventory when they reach full capacity, and continue to accumulate inventory (the correlation of capacity utilization with inventory scaled by lagged capital is 0.66 and with inventory growth is 0.58), consistent with a more aggressive sales smoothing behavior, or stocking up for bad times. Consistent with financially constrained behavior, constrained firms need to build capital much more rapidly when close to capacity than do unconstrained firms – the correlation between capacity utilization and capital growth is 0.26 for unconstrained firms but 0.58 for constrained firms.

5.2 Results on Model-generated Data

The Determinants of Inventory Holdings – Little is known about the cross-sectional determinants of inventory holdings, and even less as to why financially constrained firms hold 50 percent more inventory as a proportion of lagged capital than do unconstrained firms. To gain some intuition about the model and this question, in this section, we essentially do a series of comparative static exercises on the model-generated inventory holding levels by changing various parameters of the model. The results are summarized in Table 4.

Given a negatively sloped demand curve and stochastic and upwards sloping marginal cost curve, firms have a natural incentive to produce more when the marginal cost curve is lower, and carry inventory for sale to periods when it is higher. This incentive for inventory accumulation exists for both unconstrained and constrained firms. What makes such sales-smoothing behavior especially important for the latter is the possibility that in the bad cost states, when profits are low, they face the risk of having to sell capital or adjust capital investment too drastically, which is costly because of capital adjustment costs. If they manage to carry inventory produced in good cost states to such bad cost-low profit states, they can avoid costly capital adjustment by generating sales via depletion of inventory instead. Thus, any parameter that affects profitability in the low production cost state will affect inventory and investment behavior of constrained firms.[17]

We focus on fixed operating costs, f_0 [18] In column (1) of Table 4, we find that if we lower f_0

[17] Three elements of the argument are worth emphasizing. First, the production-cost smoothing argument implies that it is better to produce more and hold inventory in good times when costs are low, and sell from inventory in bad times when costs are high, than to simply save the cost of extra production in good times as cash and carry that over to bad times. Firms' inventory holding decision involves a trade off between the benefit of smoothing with the cost of holding inventory. Second, constrained firms are more willing to incur the cost of holding inventory in good times in return for greater sales in bad times when production costs are high. Third, constrained firms are not necessarily at a disadvantage relative to unconstrained firms in accumulating inventory in good times except immediately after an unexpected positive shock hits, since capacity constraints eventually get relaxed in good times as profits accumulate. Together, these effects produce a higher inventory-to-capital ratio for constrained firms relative to unconstrained firms, which increases as fixed operating costs that need to be covered become more important, as we shall see below.

[18] The baseline value of f_0 implies that fixed operating costs are 23 percent of production costs.

from its baseline value to zero, there is no effect on the capital investment or inventory holdings of the financially unconstrained firms. This is because the unconstrained firms do not accumulate inventory with the objective of avoiding capital depletion in bad cost states. However, the constrained firms do. So when this parameter becomes zero, the constrained firms increase capital and reduce inventory. Therefore, the inventory-to-capital ratio decreases. Lowering f_1, the cost of operations per unit of capital, has a similar effect. As shown in Column (2), it discourages inventory holding and encourages investment in capital. While the level of inventory holdings do go up slightly as production increases with capital (firms are less capacity constrained), the ratio of inventory-to-capital falls for the constrained firms. However, there is not much effect on unconstrained firms.

Next, consider the parameter of the accelerator term, b (Column (3)). A lower value reduces the penalty of being out of stock, and also the penalty for holding too much inventory in relation to sales. Unconstrained firms normally do not need to hold large amounts of inventory, since they have no concern of having to deplete capital. A higher penalty for stockout forces them to hold more inventory: when the penalty is reduced, they reduce inventory. In contrast, financially constrained firms have a need to more inventory, so when the cost of holding inventory is reduced, they significantly increase inventory holdings. There is very little effect on capital investment; thus, unconstrained decrease inventory-to-capital and constrained firms increase it when b decreases.

Investment is less flexible than inventory because it is associated with adjustment cost. When these adjustment costs decrease, firms are encouraged to invest more. This is seen in Column (4). Inventory holdings also increase, again possibly because capital increases. However, noticeably, constrained firms increase inventory much less than do unconstrained firms, consistent with the idea that these firms are less reluctant to cut capital when profits are squeezed if investment adjustment costs are lower.

Two key parameters for smoothing behavior are the slopes of the marginal cost curve and the demand curve. Consider the former first. A seen in Column (5), a steeper marginal cost curve causes both types of firms to curtail investment in capital. This is because production is likely to be lower when the marginal cost becomes steeper. However, unlike the unconstrained firms, the constrained firms increase inventory holding: the return from sales smoothing is likely to increase for these firms as profits will be even lower in the bad cost states. Similarly, a steeper demand and marginal revenue curve creates greater incentives for inventory holding, but also reduces capital and output. As Column (6) shows, both types of firms reduce capital; however, while unconstrained firms reduce inventory, constrained firms increase it, so that the ratio of inventory-to-capital increases.

Without uncertainty, there is no reason for inventory smoothing. In columns (7) and (8), we examine the effects of higher cost and demand volatility, respectively. Consider cost volatility first. In column (7), we see that higher cost volatility causes both types of firms to invest more in capital [19]. There is almost no effect on the level of inventory holding for unconstrained firms; however, constrained firms increase inventory and the inventory-to-capital ratio increases. This is because with greater volatility, the risk of more severe bad cost states increases, requiring more inventory to be carried over into these states. A similar effect occurs when demand volatility increases. Again, the net effect on the inventory-to-capital ratio for unconstrained firms is small, but the ratio increases for constrained firms.

Regression Results – Our purpose in this section is to first test whether the hypothesis of asymmetric response is valid in the model-simulated data. To do so, we regress model-generated inventory growth (change in inventory scaled by lagged capital) on the *change* in the level of the cost or demand realization scaled by its standard deviation (this is what we call a cost or demand "shock"). In addition, we include an interaction of the shock with an indicator variable that takes a value of 1 if the firm is financially constrained in the model, and 0 if it is unconstrained. We consider

[19] Since capital is costly to adjust, and firms gain more from increasing output when cost is low than they lose from cutting output when cost is high, they increase investment on average when cost volatility increases.

favorable (positive, denoted with a plus sign) and unfavorable (negative, denoted with a minus sign) shocks separately [20]. We also run exactly the same regression with growth of capital in place of inventory growth. To control for expected shocks, in these regressions we also control for the lagged state, that is, the lagged demand and cost realization.

The result reported in column (1) of Table 5 is very supportive of the asymmetric response of inventory to cost shocks. Both the positive and negative cost shock variables have significant positive coefficients, indicating that unconstrained firms add (deplete) inventory in response to positive (negative) cost shocks. The interaction of the positive cost shock with the financial constraint dummy is negative, indicating that financially constrained firms respond less sluggishly to positive shocks; in contrast, the interaction of the negative cost shock with the dummy is positive, suggesting more aggressive inventory depletion. The coefficients of both the positive and the negative demand shock are also positive. Because demand is highly persistent, demand variability causes procyclical inventory movement, consistent with arguments in Blinder (1986). Somewhat surprisingly, the interaction with both the positive and negative demand shocks are positive. Constrained firms deplete inventory more aggressively when a negative demand shock hits, but they also accumulate inventory more aggressively when there is a positive demand shock. One possible explanation for the latter result is that the much smaller volatility of demand shock means that the production capacity limit is not reached very often when a positive demand shock hits in our model (since the more volatile cost shocks are also present, firms are encouraged to invest higher amounts). Constrained firms respond to a positive demand shock by accumulating inventory more aggressively, possibly because they utilize capacity more fully in anticipation of being capacity constrained while demand is still high.

Turning to the regression of capital growth on the shocks and their interactions with the financial constraint dummy, the results reported in column (2), again, are largely consistent with our hypothesis. For cost shocks, the results exactly mirror those for the inventory regression. For

[20] Recall that a cost shock is the negative of a change in the level of the cost realization.

demand shocks, the results for unconstrained firms mirror those for the inventory regressions; however, the interaction terms are insignificant. This is consistent with our explanation for inventory behavior of constrained firms in response to positive demand shocks suggested above. If the shock is not large, both types of firms may be accommodate it with moderate increases of capital.

Next, we examine the extent to which sales growth (or sales shocks) are a good proxy for the underlying cost and demand shocks. In the actual data, we do not observe the shocks to cost and demand, but we do observe shocks to sales, which is likely to be highly correlated with the former. In Table 6, we verify that this is indeed the case by regressing sales growth (change in sales scaled by lagged capital) on demand and cost shocks standardized by their respective standard deviations. Consistent with our expectation, both shocks are significantly and positively related to sales growth. The regression R^2 is high – about 40 percent. While the interaction terms are significant, they are a tenth of the magnitude of the coefficient of the uninteracted terms, suggesting that in regressions in which sales growth is proxy for shocks to demand and cost, it is unlikely that differences in the coefficients of sales growth for constrained and unconstrained firms is driven by different degrees of measurement error. Moreover, since the sales response to shocks is approximately the same for constrained and unconstrained firms, these results suggest that any difference in the response of inventory to shocks is likely driven by differences in the response of production to these shocks, which could reflect the presence of more binding capacity constraints for constrained firms.

We next turn to regressions on the simulated data where sales growth proxy for shocks to cost and demand. We first discuss the results of regressing inventory growth on sales growth, reported in the first three columns of table 7.

The baseline regression of inventory growth on sales growth is reported in column (1) of Table 7. Sales growth is again split into positive and negative growth, and each is interacted with a financial constraint dummy. We control for the financial constraint dummy, and the lagged value of inventory over lagged capital. In both columns, we also include a dummy variable, *Below*, and its interaction with the financial constraint dummy. *Below* takes a value of 1 if the firm's lagged sales growth is below the 10th percentile, and zero otherwise. The motivation is to see whether firms in our model, especially financially constrained ones, deplete more inventory when the shock is extremely adverse. Moreover, we control for lagged cash flow, which has the highest correlation with the demand and cost realizations among all other financial variables in Table 3, to control for expected shocks to sales.

The regression of inventory growth on sales growth and its interactions with the financial constraint dummy is very consistent with those we observed when the cost and sales shocks were directly included. In fact, the coefficients on sales growth can be approximately derived directly from the regressions reported in the above Tables because $\frac{\partial \Delta N_t}{\partial SG} = \frac{\partial \Delta N_t}{\partial Shock} \frac{\partial Shock}{\partial SG}$, where SG denotes sales growth. Interestingly, this approximation only works for the cost shock, suggesting that cost shocks are mainly responsible for the sales-inventory relationship.

We also find very consistent results for the *Below* dummy. Both the dummy and its interaction are significantly negative, and the coefficient estimate on the interaction term is quite large. Firms deplete inventory more rapidly when the sales shock is very adverse, and constrained firms do so more aggressively.

One concern with these estimates may be that because we do not allow firm exit, the simulated sample may have a much higher percentage of negative cash flow firms than in the real data, and this could be affecting our results. To mitigate this concern, in column (2) of Table 7, we drop firm years after four consecutive periods with cash flow lower than -10 percent. The results are largely unchanged. The only significant difference is that, somewhat surprisingly, the financially constrained firms now deplete inventory in response to a negative sales shock even more aggressively. One possible explanation for this result is that if firms become too unprofitable, they may run out of inventory, and start depleting capital. Removing these firms may then result in a higher sensitivity of inventory to negative sales growth.

Finally, we note that in the regressions in columns (1)-(2), the coefficient on negative sales growth is somewhat larger than for positive sales growth. One possible reason for this is that while in the model firms face no constraints in depleting inventory, even unconstrained firms in the model face capacity constraints (since capital is committed one period early for production) and adjustment costs of increasing production capacity when they want to increase inventory. There may be many real-world reasons, however, why the costs of inventory depletion could also be high. For example, firms may have hired workers on long-term contracts or entered into such contracts with suppliers, in which case there may be costs to cutting production, which would result in smaller inventory depletion. In column (3) of Table 7, we add a term $-d3 * (q_t - q_{t-1})^3$ where $d3 > 0$ to the cost function to capture the costs associated with cutting production. As expected, the coefficient on negative sales growth decreases, while that on positive sales growth increases. This simple observation will be useful in understanding the results of estimating the baseline model on the real data.

Since contemporaneous sales and inventory growth are jointly determined, there may be concern about endogeneity. To address this issue, we repeat the regressions of Table 7 by lagging sales growth one period, and the *Below* dummy and cash flows one more period. The results in the first three columns of Table 8 are very consistent with the corresponding ones in Table 7. The signs of the coefficients of positive and negative lagged sales growth and their interaction with the financial constraint dummy are exactly as those for contemporaneous sales growth. With the exception of the interaction of negative sales growth with the financial constraint dummy, the coefficients are smaller in magnitude. The gap in the response of the unconstrained and constrained firms to a positive sales shock becomes weaker : this is expected since capacity constraints are expected to become less binding for both types of firms [21] , and especially for the constrained firms. However,

[21]Recall that since capital is committed one period ahead of production, even the unconstrained firms face capacity constraints.

the constrained firms respond to lagged negative sales shocks even more aggressively. The two-period lagged *Below* dummy interacted with the financial constraint dummy remains negative and significant, and the economic magnitude of the coefficient remains as important.

Next, we turn to the regression of capital growth on sales growth, reported in columns (4)-(6) of Table 7. We use an almost identical specification as for inventory growth. While capital growth responds positively to positive sales shocks, consistent with financially constrained behavior, constrained firms respond somewhat more sluggishly. On the other hand, while both types of firms reduce capital growth in response to negative sales shocks, constrained firms do so more aggressively. Results are similar for the subsample of firms that drops firm years with four consecutive cash flows less than -10 percent, and also when firms are penalized for reducing output too rapidly.

Results based on lagged sales growth, reported in the last three columns of Table 8, are almost identical.

5.3 Results on Actual Data

When we estimate the baseline model on real data, we incorporate firm fixed affects and to account for seasonality, we run regressions for each quarter. Regression results with inventory growth as the dependent variable for all four quarters are reported in Table 9. The results for positive sales growth are similar to what we observe in Table 7. Unconstrained firms respond to positive sales shocks by increasing inventory; constrained firms follow suit, but less aggressively. This is consistent with our hypothesis and the model.

For negative sales growth, however, we do not see any consistent pattern. Firms appear not to adjust inventory when sales growth drops. However, when sales growth drops sharply – i.e., below the firm-level 10th percentile cutoff – both unconstrained and constrained firms deplete inventory, and the latter deplete more. These results are consistent with the model and the results in Table 7.

In Table 10, where we repeat the same regressions on lagged sales growth instead of the contemporaneous one, we do see constrained firms reduce inventory in response to negative sales shocks with a lag. The responses to positive sales shocks, however, get weaker at one period lag, and in two of the quarters, the interaction of positive sales growth with the financial constraint dummy become insignificant. Overall, this pattern that the upside responses become weaker and the downside response for the financially constrained firms becomes stronger at one period lag is very consistent with the results in tables 7 and 8. Moreover, also consistent with the results in these tables, in table 10, the *Below* dummy lagged two periods interacted with the financial constraint dummy continues to be significantly negative; however, we do not find a consistent pattern for unconstrained firms.

The lack of sensitivity of inventory to contemporaneous moderately negative sales declines is puzzling. One possibility is that firms face costs of cutting production immediately (that is, within the quarter) due to pre-existing contracts with labor or suppliers. Since these are essentially committed fixed costs, the firm cannot save these costs by cutting production, so it might as well produce and maintain its inventory. This is precisely the effect we notice in column (3) of Table 7 – the sensitivity of inventory to a sales drop decreases when it is more costly to cut output. This interpretation is also consistent with the evidence documented above that, at least for constrained firms (who may have the most need to cut production costs), inventory declines with a lag for negative sales shocks.

Another possibility is that firms may have converted inventory accumulated when production costs were low to cash by gradually depleting inventory and holding cash as a buffer against bad cost shocks. Converting inventory to cash to avoid inventory holding costs would make sense as long as stockout costs are not very high. Constrained firms may run out of cash faster when faced with negative shocks, and may deplete inventory with a lag.

In Table 11, we report results on PPE growth and Capex. Results are mostly consistent with our hypothesis and those in Table 7, especially for positive sales shocks. For positive sales shocks, while both unconstrained and constrained firms increase both PPE growth and Capex, the latter do so less aggressively. There are some differences, however, when the sales shock is negative. Somewhat surprisingly, unconstrained firms increase Capex when sales drop; however, constrained firms reduce Capex, and more so when sales drop below the bottom 10 percent cutoff for sales, consistent with our hypothesis. With respect to PPE, unconstrained firms do cut PPE growth when there is a negative sales shock; however, there is no evidence that the constrained firms do so more aggressively. Results in Table 12 where we regress Capex and PPE growth on lagged sales are similar, but the magnitudes are smaller, as expected.

Overall, the results on capital growth, especially the response to positive sales growth, line up well with the model results. This is the direction of response to unanticipated sales shocks that is more important for our hypothesis that binding capacity constraints affect the relative sensitivity of the response of inventory growth (or production, holding sales shock constant) of financially unconstrained and constrained firms. The relative sensitivity of Capex to negative sales shocks is very consistent with the model; but less so for PPE growth. However, it is conceivable that the ability to deplete inventory carried over from good times in bad times allows the financially constrained firms to avoid depleting capital relative to the unconstrained firms, as indicated by the PPE growth results.

The capital growth results are important for another reason as well. As noted in the introduction, our model is primarily one for finished goods inventory. However, intermediate goods inventory can be modeled as a factor of production similar to capital, and is held in relative fixed proportion to capital, would generate results very similar to those for capital growth in our model – namely, that financially constrained firms increase intermediate goods inventory more sluggishly in response to positive sales shocks, and reduce such inventory more aggressively in response to negative sales shocks, than do unconstrained firms. As noted, these implications are very consistent with our inventory regressions on the actual data.

5.4 The Cumulative Effect of Past Sales Shocks

In the results presented so far, we have mainly focused on the immediate response of inventory to shocks to sales. We have paid particular attention to a key asymmetry implied by the model, i.e., due to capacity constraints, the inventory accumulation by constrained firms in response to favorable shocks is more sluggish than that of unconstrained firms, but more aggressive in response to unfavorable shocks.

What remains to be shown is that once capacity constraints become less binding as profitability improves in favorable cost states, the response of the constrained firms to positive and negative sales shocks becomes more symmetric vis-a-vis unconstrained firms, that is, the former respond more aggressively in response to both types of shocks. This is what is implied by the model. The key insight from the model is that financially constrained firms engage in more aggressive production-cost smoothing because they benefit more from accumulating inventory in low production-cost states, and selling from inventory in high production cost states (when financial constraints are more likely to be binding). We now provide evidence consistent with this behavior [22].

To do so, we examine the cumulative lagged effects of shocks on the inventory behavior of both types of firms. We focus on extreme shocks and use a specification very similar to that in Table 9. Specifically, we create an *Above* dummy that takes a value of 1 in a given quarter if a firm's sales growth exceeds the 90th percentile of the distribution for that firm, and zero otherwise. This is analogous to the *Below* dummy in Table 9 which corresponds to sales growth lower than the 10th percentile of the distribution. We then include up to six lags of the *Above* and *Below* dummies, and their interactions with the financial constraint dummy, in specifications similar to that in Table 9.

[22] While we do not model cash holding behavior, constrained firms would generally find it optimal to hold cash if that possibility were introduced. However, the result that constrained firms accumulate (deplete) inventory more aggressively in good (bad) cost states than unconstrained firms do, continues to hold if the former are allowed to hold cash, as long as there is a carry cost of cash holdings. This is shown in the Appendix. Unconstrained firms in our model do not have any incentive to hold cash.

We also control for the financial constraint dummy, contemporaneous positive and negative sales growth, cash flow and the interaction of cash flow with the financial constraint dummy, the lagged ratio of inventory to lagged capital and its interaction with the financial constraint dummy.

Column (1) in Table 13 report results for the simulated data. Consistent with a symmetric and more aggressive response to both positive and negative extreme sales shocks, the cumulative coefficients of the lagged *Above* and *Below* dummies interacted with the financial constraint dummy are, respectively, positive and negative. This suggests that over six periods after an extreme shocks, the financially constrained firms not only accumulate more inventory in response to a positive extreme sales shock, they also deplete more inventory in response to a negative extreme sales shock, than their unconstrained counterparts.

Column (2) reports the results for the real data. The regressions are run for each quarter, and the average coefficients over all quarters in a year are reported. For the lags of the *Above* and *Below* dummies, the reported coefficients are further cumulated over the six lags. The results are very consistent with those in column (1). In particular, the cumulative coefficients of the *Above* dummy interacted with the financial constraint dummy is positive and significant, while that of the *Below* dummy is negative and significant.

6 Conclusion

Changes to firms' inventory holdings have long been regarded as an important component of business fluctuations, as has the propagation of monetary policy shocks to the real economy via firms' access to finance. While earlier empirical attempts either found little relationship between the cost of finance and inventory holding behavior, more recent evidence suggests that monetary policy may have important effects on the inventory holding behavior of firms that have difficulty in accessing external finance. There has been little attempt, however, to link the effect of financial constraints to inventory policy theoretically.

In this paper, we develop a theoretical model that studies the interaction of financial constraints and inventory behavior. The main intuition we try to model is that firms' incentives to build inventory when costs are low and deplete inventory when costs are high are exacerbated when they face financial constraints and have difficulty in rebuilding capital. The model provides a number of insights on the determinants of inventory holdings in the presence of financial constraints. Using model-generated data, we develop several empirical tests of the theory. These tests have the advantage that we do not need to interpret coefficients of cash flows in our regressions, which has been controversial due to measurement error issues. When we take these tests to the actual data, we find very consistent results.

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A Model with Cash Holdings

In this appendix, we explore the effect of cash holdings on firms' inventory investment behavior by analyzing a special case under which an analytical analysis is available. Cash holdings are assumed to have no additional benefits except to hedge for liquidity risks, i.e., the one-period return of cash holdings, R^H, is lower than or equal to the risk free rate $1/\beta$. Therefore, financially unconstrained firms hold zero cash but financially constrained firms generally hold nonzero cash under this assumption. We argue that even in the presence of cash holdings, financially contained firms hold more inventory in good times and less inventory in bad times, compared to financially unconstrained firms.

Define $\lambda_t = 1 + \frac{1}{\varpi_1 \tilde{D}_{t+1}}$ and rewrite the FOC of inventory in equations (6) for constrained firms as

$$e^{X_t} - H_t = \beta \mathbb{E}_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[e^{X_{t+1}} - G_{t+1} \right] \right\} \tag{12}$$

and the FOC of inventory for unconstrained firms in (9) as

$$e^{X_t} - H_t = \beta \mathbb{E}_t \left\{ \left[e^{X_{t+1}} - G_{t+1} \right] \right\} . \tag{13}$$

Here, λ_t measures the tightness of the financial constraints. In good times, the current dividend is high and future dividend is expected to be lower due to the mean-reverting demand and cost shocks and vice versa for bad times. Therefore, we have

$$\frac{\lambda_{t+1}}{\lambda_t} > 1 \quad \text{for good times;} \quad \frac{\lambda_{t+1}}{\lambda_t} < 1 \quad \text{for bad times.}$$

It can be easily shown that

$$\frac{\partial H_t}{\partial N_t} < 0 \quad \text{and} \quad \frac{\partial G_{t+1}}{\partial N_t} < 0 \, .$$

Therefore, all else equal, constrained firms will hold more inventory in good times and hold less inventory in bad times than unconstrained firms.

Now assume that we allow cash holdings, denoted as CH_t. Dividend is then given by

$$D_t = Y_t - C_{Ot} - C_{Qt} - C_{Nt} - C_{It} - I_t + R^H \, CH_{t-1} - CH_t \, .$$

Since cash holding has to be positive, we introduce an additional term

$$\frac{\log(CH_t)}{\varpi_3}$$

to approximate this nonnegative-cash-holding constraint, where $\varpi_3 \to \infty$ so that the above term is close to zero when $CH_t > 0$. As we argue before, unconstrained firms will hold zero cash. The optimal cash holdings of constrained firms is given by the following FOC:

$$\lambda_t = \beta R^H \mathbb{E}_t \left[\lambda_{t+1}\right] + \frac{1}{\varpi_3 CH_t} \,. \tag{14}$$

The model generally has no analytical solution. To illustrate the mechanism, let's consider a special case where there is no uncertainty and agents know the time series of demand and cost shocks at time 0. Then we can substitute equation (14) into equation (12) and get

$$e^{X_t} - H_t = \beta \mathbb{E}_t \left\{ \left(\frac{1}{\beta R^H + \frac{1}{\varpi_3 \, CH_t \, \lambda_{t+1}}} \right) \left[e^{X_{t+1}} - G_{t+1} \right] \right\} . \tag{15}$$

In this case, whether constrained firms will hold more or less inventory than unconstrained firms depends on whether

$$\frac{1}{\beta R^H + \frac{1}{\varpi_3 \, CH_t \, \lambda_{t+1}}} > 1 \quad \text{or} \quad < 1 \,, \tag{16}$$

respectively. In good times, $CH_t > 0$ and $\varpi_3 \, CH_t \, \lambda_{t+1} \to \infty$. Therefore, as long as $R^H < 1/\beta$, i.e., there are costs associated with cash holdings, condition (16) is larger than one and constrained firms will hold more inventory. On the contrary, in bad times, constrained firms have cash holdings close to zero and the term $\varpi_3 \, CH_t \, \lambda_{t+1}$ could be a finite number (this term is always positive by definition). When cash holdings are low enough, we could have

$$\frac{1}{\beta R^H + \frac{1}{\varpi_3 \, CH_t \, \lambda_{t+1}}} < 1 \,,$$

that is, constrained firms hold less inventory than unconstrained firms in an extremely bad situation even in the presence of cash holdings. A more general case has to be solved numerically and our argument can be shown through numerical exercises.

Table 1: **Baseline Calibration**

This table lists the parameter values used to solve and simulate the baseline model. Section 4 discussed how the model is calibrated. Parameters are reported at quarterly frequency.

Parameters	Benchmark Values	Description
α	0.70	Capital-to-output ratio
g	1.009	Growth rate of productivity
β	0.982	Time-preference coefficient
δ	0.015	Capital depreciation rate
a	60	Quadratic investment adjustment cost
h	0.01	Slope of demand curve
A_0	3	Scaling factor in capacity constraint
c	2.08	Stockout-avoidance ratio
b	0.0032	Stockout-avoidance cost
γ	1.5	Elasticity of stockout-avoidance cost to sales
d_1	0.132	Linear production cost
d_2	0.022	Quadratic production cost
$\bar{X}$	-1.45	Long-run average of demand shock
ρ_X	0.985	Persistence coefficient of demand shock
ρ_Z	0.941	Persistence coefficient of cost shock
σ_X	0.0292	Conditional volatility of demand shock
σ_Z	0.125	Conditional volatility of cost shock
f_0	0.0665	Fixed operating cost
f_1	0.0069	Linear operating cost

Table 2: **Summary Statistics**

This table presents the summary statistics of real data and the unconditional sample moments from simulated data. In both panels, statistics are reported separately for the Financial Unconstrained firms (UFC) and Financially Constrained firms (FC). Real data used in Panel A are collected from *Compustat* Industrial Quarterly Files for the period 1971 to 2010. Financial firms (SIC Code 6000-6900) and regulated utilities (SIC Code 4900-4999) are excluded. UFC and FC in real data are classified based on size. In a given quarter, UFC are the top 30% in beginning-period total asset and FC are the bottom 30%. K_t is the level of Capital defined as total asset (ATQ) minus inventory (INVTQ), $INVT_t$ is the level of inventory adjusting for the LIFO and FIFO accounting. $Sales_t$ is the level of net sales (SALEQ). Levels are converted to 2000 constant dollars. $Invt_t/K_{t-1}$ is inventory scaled by lagged capital. $Sales_t/K_{t-1}$ is sales scaled by lagged capital. $CapitalGrowth$, $InvtGrowth$, $SalesGrowth$ and $PPEGrowth$ are defined as change in the levels of capital, inventory, sales and property plant and equipment (PPENTQ), scaled by lagged capital. $Capex_t/K_{t-1}$ is the quarterly capital expenditure calculated by converting the *Compustat* Year-to-Date item CAPXY to quarterly frequency and then scaled by lagged capital. CF_t/K_{t-1} is earnings before extraordinary items (IBQ) plus depreciation (DPQ) scaled by lagged capital. Ratios and changes are winsorized at 1% levels at both tails to mitigate the effect of outliers. Data in Panel B are generate from 100 simulated panels, each contains 720 quarters for 300 UFC and 300 FC firms. UFC are firms that can seek external financing with no cost. FC are firms whose dividend have to be nonnegative. In the simulated data, $Invt_t/K_{t-1}$ is the stock of goods firms carry in dollar value scaled by lagged capital, $Sales_t/K_{t-1}$ is sales in dollars scaled by lagged capital. $Prod_t/K_{t-1}$ is the output in dollars scaled by lagged capital. $InvtGrowth$ and $SalesGrowth$ are defined as change in the level of inventory and sales scaled by lagged capital. $Investment$ is change of capital net of depreciation scaled by lagged capital. CF_t/K_{t-1} is cash flow calculated by subtracting production cost, operating cost, and investment adjustment cost from sales, scaled by lagged capital. $Utilization$ is the proportion of capital that firms actually used to generate output over the total beginning-period stock of capital. Reported statistics including mean, median and standard deviation (SD) for the simulated data are calculated as cross-simulation averages.

Panel A. Real Data

	UFC				FC			
	N	Mean	Median	SD	N	Mean	Median	SD
K_t (th. \$)	140,777	6,552,544	1,900,683	19,512,585	140,689	41,347	34,793	27,526
$Invt_t$ (th. \$)	140,777	815,569	284,975	1,876,769	140,689	9,826	6,228	11,880
$Sales_t$ (th. \$)	140,777	1,706,686	581,187	4,238,770	140,689	16,880	12,093	18,139
$Invt_t/K_{t-1}$	140,777	0.2413	0.1475	0.3202	140,689	0.3229	0.1935	0.4094
$Sales_t/K_{t-1}$	140,777	0.3859	0.2932	0.3515	140,689	0.4754	0.3861	0.4173
$CapitalGrowth$	140,777	0.0151	0.0031	0.1046	140,689	0.0313	0.0004	0.1774
$InvtGrowth$	140,777	0.0019	0.0000	0.0435	140,689	0.0041	0.0000	0.0653
$SalesGrowth$	140,777	0.0053	0.0026	0.0896	140,689	0.0102	0.0031	0.1288
$PPEGrowth$	139,623	0.0043	0.0002	0.0349	140,253	0.0060	-0.0012	0.0432
$Capex_t/K_{t-1}$	115,201	0.0206	0.0153	0.0195	114,936	0.0208	0.0103	0.0289
CF_t/K_{t-1}	122,893	0.0276	0.0282	0.0326	120,244	0.0110	0.0225	0.0640

Panel B. Simulated Data

	UFC				FC			
	N	Mean	Median	SD	N	Mean	Median	SD
$Invt_t/K_{t-1}$	215,700	0.1485	0.1640	0.0466	215,700	0.2106	0.2270	0.1165
$Sales_t/K_{t-1}$	215,700	0.5017	0.5214	0.1422	215,700	0.5694	0.5738	0.1484
$Prod_t/K_{t-1}$	215,700	0.5031	0.5251	0.1475	215,700	0.5722	0.5799	0.1592
$InvtGrowth$	215,700	0.0015	0.0029	0.0173	215,700	0.0029	0.0051	0.0250
$SalesGrowth$	215,700	0.0055	0.0065	0.0547	215,700	0.0073	0.0075	0.0587
$Investment$	215,700	0.0242	0.0228	0.0178	215,700	0.0243	0.0247	0.0230
CF_t/K_{t-1}	215,700	0.0440	0.0623	0.1147	215,700	0.0316	0.0536	0.2783
$Utilization$	215,700	0.6788	0.7568	0.2286	215,700	0.7340	0.8097	0.2137

Table 3: **Correlation Matrix of Simulated Data**

This table reports the cross-simulation average of the pairwise correlation coefficients. Data are generated from 100 simulations. Each simulation has 1440 quarters and 600 firms, of which 300 are UFC and 300 are FC. Correlations for the UFC group are reported in Panel A and for the FC group are in Panel B. Variable definitions are included in Table 2. 95% confidence intervals for all the correlations do not span zero.

Panel A. Correlation matrix of UFC in simulated data

	$Invt_t/K_{t-1}$	$Sales_t/K_{t-1}$	$InvtGrowth$	$SalesGrowth$	$Investment$	CF_t/K_{t-1}	$Utilization$	$Cost$	$Demand$
$Invt_t/K_{t-1}$	1.000								
$Sales_t/K_{t-1}$	0.861	1.000							
$InvtGrowth$	0.233	0.279	1.000						
$SalesGrowth$	0.188	0.275	0.922	1.000					
$Investment$	0.259	0.440	0.154	0.182	1.000				
CF_t/K_{t-1}	0.570	0.527	0.066	0.056	0.432	1.000			
$Utilization$	0.965	0.865	0.393	0.329	0.268	0.650	1.000		
$Cost$	0.466	0.283	0.160	0.134	0.630	0.695	0.497	1.000	
$Demand$	0.045	0.391	0.028	0.057	0.279	0.495	0.158	-0.002	1.000

Panel B. Correlation matrix of FC in simulated data

	$Invt_t/K_{t-1}$	$Sales_t/K_{t-1}$	$InvtGrowth$	$SalesGrowth$	$Investment$	CF_t/K_{t-1}	$Utilization$	$Cost$	$Demand$
$Invt_t/K_{t-1}$	1.000								
$Sales_t/K_{t-1}$	0.338	1.000							
$InvtGrowth$	0.190	0.395	1.000						
$SalesGrowth$	0.008	0.354	0.526	1.000					
$Investment$	0.380	0.696	0.320	0.256	1.000				
CF_t/K_{t-1}	0.301	0.073	0.026	0.005	0.284	1.000			
$Utilization$	0.665	0.722	0.579	0.330	0.584	0.398	1.000		
$Cost$	0.336	0.193	0.197	0.139	0.650	0.560	0.525	1.000	
$Demand$	-0.020	0.382	0.021	0.059	0.220	0.428	0.170	-0.001	1.000

Table 4: **Comparative Statics**

This table shows the comparative statics for our baseline model. Parameter descriptions are included in Table 1. In each column from (1) to (8), one parameter value is changed each time while others are fixed at baseline. The top row shows new value for each parameter of interest. The corresponding parameter value in the baseline model is listed below for comparison. All the results are obtained with the same realization of shocks. Moments include capital level (K), inventory level ($INVT$) and inventory-to-capital ratio ($INVT/K$). For each of these moments, we listed the value for UFC, FC and the difference between the two groups, where UFC are firms that can seek external financing with no cost and FC are firms whose dividend have to be nonnegative. Moments under baseline parameters are also reported.

Variable	Sample	Baseline	(1) zero f_0	(2) zero f_1	(3) low b	(4) low a	(5) high d_2	(6) high h	(7) high σ_Z	(8) high σ_X
	New Parameter Value		f_0=0.0000	f_1=0.0000	b=0.0017	a=26	d_2=0.0096	h=0.03	σ_Z=0.165	σ_X=0.0602
	Parameter Value in Baseline		f_0=0.0665	f_1=0.0069	b=0.0032	a=60	d_2=0.0080	h=0.01	σ_Z=0.125	σ_X=0.0292
K										
	UFC	84,385	84,385	95,452	84,542	117,947	76,573	71,372	94,485	116,206
	FC	69,516	79,195	79,953	69,647	99,573	57,409	54,565	69,813	84,363
	Diff (UFC-FC)	14,869	5,190	15,499	14,895	18,374	19,164	16,807	24,672	31,843
$Invt$										
	UFC	12,353	12,353	13,226	5,870	15,015	10,520	10,314	12,028	14,948
	FC	14,992	12,343	15,182	23,605	16,455	17,846	16,561	18,819	19,653
	Diff (UFC-FC)	-2,639	10	-1,956	-17,735	-1,440	-7,326	-6,247	-6,791	-4,705
$Invt/K$										
	UFC	0.1481	0.1481	0.1404	0.0700	0.1301	0.1389	0.1453	0.1300	0.1344
	FC	0.2097	0.1570	0.1867	0.3294	0.1632	0.2881	0.2805	0.2548	0.2246
	Diff (UFC-FC)	-0.0616	-0.0089	-0.0463	-0.2594	-0.0331	-0.1492	-0.1352	-0.1248	-0.0902

Table 5: **Regression on Shocks with Simulated Data**

This table reports the regression result for the simulated data. The dependent variables are $InvtGrowth$ and $Investment$. Both are defined in Table 2. FC is a dummy that equals to 1 if the firm is FC, and 0 otherwise. $CostShock_t$ is defined as the negative of the change in level of cost realization scaled by its standard deviation. $CostShock_t^+$ is the interaction of $CostShock_t$ with an indicator that equals to 1 if $CostShock$ is positive (favorable). $CostShock_t^+ \times FC$ is the interaction of $CostShock_t^+$ with the FC dummy. $CostShock_t^-$ is the interaction of $CostShock_t$ with an indicator that equals to 1 if $CostShock_t$ is negative (unfavorable). $CostShock_t^- \times FC$ is $CostShock_t^-$ interacted with FC. In the same way, $DemandShock_t$ is defined as the change in level of demand scaled by its standard deviation. $DemandShock_t^+$ is the interaction of $DemandShock_t$ with an indicator that equals to 1 if $DemandShock_t$ is positive (favorable). $DemandShock_t^+ \times FC$ is the interaction of $DemandShock_t^+$ with the FC dummy. $DemandShock_t^-$ is the interaction of $DemandShock$ with an indicator that equals to 1 if $DemandShock_t$ is negative (unfavorable). $DemandShock_t^- \times FC$ is the interaction of $DemandShock_t^-$ with the dummy FC. $Invt_{t-1}/K_{t-2}$ is the lagged inventory-to-capital ratio. The simulated data are generate from 100 simulations. Cross-simulation average of regression coefficients are reported. 95% confidence interval is included in brackets. All the confidence intervals do not span zero.

	(1) $InvtGrowth$	(2) $Investment$
FC	0.0044	0.0018
	[0.0044, 0.0045]	[0.0017, 0.0019]
$CostShock_t^+$	0.0069	0.0079
	[0.0069, 0.0070]	[0.0078, 0.0079]
$CostShock_t^+ \times FC$	-0.0031	-0.0015
	[-0.0031, -0.0031]	[-0.0016, -0.0015]
$CostShock_t^-$	0.0086	0.0049
	[0.0086, 0.0087]	[0.0049, 0.0049]
$CostShock_t^- \times FC$	0.0021	0.0032
	[0.0021, 0.0022]	[0.0032, 0.0032]
$DemandShock_t^+$	0.0020	0.0032
	[0.0020, 0.0020]	[0.0031, 0.0032]
$DemandShock_t^+ \times FC$	0.0017	0.000067
	[0.0017, 0.0017]	[0.00004, 0.0001]
$DemandShock_t^-$	0.0024	0.0030
	[0.0024, 0.0024]	[0.0029, 0.0030]
$DemandShock_t^- \times FC$	0.0020	0.000025
	[0.0020, 0.0020]	[0.000001, 0.00005]
$Cost_{t-1}$	0.0025	0.0128
	[0.0025, 0.0025]	[0.0128, 0.0128]
$Demand_{t-1}$	0.00028	0.0048
	[0.0003, 0.0003]	[0.0048, 0.0048]
$Invt_{t-1}/K_{t-2}$	-0.0165	
	[-0.0166, -0.0164]	
$Constant$	0.0097	0.0282
	[0.0097, 0.0098]	[0.0281, 0.0284]
Observations	430, 800	431,400
$Adj.R^2$	0.159	0.490

Table 6: **Sales Growth and Shocks**

This table reports the regression result on the simulated data. The dependent variable $SalesGrowth$ is defined in Table 2. $CostShock_t$ is defined as the negative of the change in level of cost realization scaled by its standard deviation. $CostShock_t \times FC$ is the interaction of $CostShock_t$ with the dummy FC that equals to 1 if the firm is FC, and 0 otherwise. $DemandShock_t$ is defined as the change in level of demand realization scaled by its standard deviation. $DemandShock_t \times FC$ is the interaction of $DemandShock_t$ with the dummy FC that equals to 1 if the firm is FC, and 0 otherwise. The reported estimates are the cross-simulation average of the coefficients from 100 simulations. 95% confidence intervals are included in brackets. All the confidence intervals do not span zero.

	(1) $SalesGrowth$	(2) $SalesGrowth$	(3) $SalesGrowth$
$CostShock_t$	0.0250	0.0250	
	[0.0249, 0.0250]	[0.0249, 0.0250]	
$CostShock_t \times FC$	0.0023	0.0023	
	[0.0021, 0.0024]	[0.0021, 0.0024]	
$DemandShock_t$	0.0208		0.0208
	[0.0207, 0.0208]		[0.0207, 0.0208]
$DemandShock_t \times FC$	0.0022		0.0022
	[0.0021, 0.0022]		[0.0021, 0.0022]
$Constant$	0.0064	0.0064	0.0064
	[0.0064, 0.0064]	[0.0064, 0.0064]	[0.0064, 0.0064]
Observations	431,400	431,400	431,400
$Adj.R^2$	0.361	0.212	0.149

Table 7: **Regression on Sales Growth with Simulated Data**

This table reports the regression results on the simulated data. The dependent variables $InvtGrowth$ and $Investment$ are defined in Table 2. FC is defined in Table 5. $SalesGrowth_t^+$ is the interaction of $SalesGrowth_t$ and an indicator which equals to 1 if $SalesGrowth_t$ is positive, and 0 otherwise. $SalesGrowth_t^-$ is the interaction of $SalesGrowth_t$ and an indicator which equals to 1 if $SalesGrowth_t$ is negative, and 0 otherwise. $SalesGrowth_t^+ \times FC$ and $SalesGrowth_t^- \times FC$ are the interactions of $SalesGrowth_t^+$ with FC and $SalesGrowth_t^-$ with FC, respectively. $Below_{t-1}$ is a dummy that equals to 1 if $SalesGrowth_{t-1}$ is below the 10th percentile of the firms' distribution. $Below_{t-1} \times FC$ is $Below_{t-1}$ interacted with FC. CF_{t-1}/K_{t-2} is the lagged cash flow-to-capital ratio. $CF_{t-1}/K_{t-2} \times FC$ is CF_{t-1}/K_{t-2} interacted with FC. $Invt_{t-1}/K_{t-2}$ is the lagged inventory-to-capital ratio. The reported estimates are the cross-simulation average of the coefficients from 100 simulations. 95% confidence intervals are included in brackets. All the confidence intervals do not span zero.

	Baseline	With Exit	Cubic Cost	Baseline	With Exit	Cubic Cost
	(1)	(2)	(3)	(4)	(5)	(6)
	$InvtGrowth$	$InvtGrowth$	$InvtGrowth$	$Investment$	$Investment$	$Investment$
FC	0.0076	0.0083	0.0087	0.0060	0.0058	0.0053
	[0.0075, 0.0076]	[0.0082, 0.0084]	[0.0087, 0.0087]	[0.0059, 0.0061]	[0.0055, 0.0062]	[0.0051, 0.0054]
$SalesGrowth_t^+$	0.2444	0.2578	0.2824	0.1043	0.1004	0.0719
	[0.2442, 0.2446]	[0.2573, 0.2583]	[0.2821, 0.2827]	[0.1039, 0.1046]	[0.0999, 0.1009]	[0.0715, 0.0723]
$SalesGrowth_t^+ \times FC$	-0.1413	-0.1051	-0.1723	-0.0296	-0.0681	-0.0118
	[-0.1418, -0.1407]	[-0.1062, -0.1041]	[-0.1729, -0.1718]	[-0.0317, -0.0276]	[-0.0693, -0.0669]	[-0.0136, -0.0101]
$SalesGrowth_t^-$	0.3408	0.3489	0.2980	0.0331	0.0179	0.0548
	[0.3405, 0.3410]	[0.3483, 0.3494]	[0.2978, 0.2982]	[0.0326, 0.0335]	[0.0171, 0.0186]	[0.0543, 0.0554]
$SalesGrowth_t^- \times FC$	0.0301	0.0949	0.0600	0.1206	0.1275	0.1201
	[0.0289, 0.0314]	[0.0926, 0.0972]	[0.0589, 0.0612]	[0.1189, 0.1222]	[0.1263, 0.1287]	[0.1184, 0.1219]
$Below_{t-1}$	-0.0030	-0.0026	-0.0042	-0.0030	0.0002	-0.0009
	[-0.0030, -0.0030]	[-0.0026, -0.0026]	[-0.0042, -0.0042]	[-0.0030, -0.0029]	[0.0002, 0.0003]	[-0.0009, -0.0008]
$Below_{t-1} \times FC$	-0.0136	-0.0141	-0.0101	-0.0120	-0.0089	-0.0126
	[-0.0136, -0.0135]	[-0.0142, -0.0140]	[-0.0101, -0.0100]	[-0.0121, -0.0119]	[-0.0090, -0.0087]	[-0.0128, -0.0124]
CF_{t-1}/K_{t-2}	0.0018	0.0044	0.0087	0.0625	0.0995	0.0483
	[0.0017, 0.0018]	[0.0044, 0.0045]	[0.0086, 0.0087]	[0.0622, 0.0628]	[0.0991, 0.0999]	[0.0479, 0.0487]
$CF_{t-1}/K_{t-2} \times FC$	-0.0056	-0.0153	-0.0091	-0.0391	-0.0345	-0.0266
	[-0.0058, -0.0053]	[-0.0158, -0.0147]	[-0.0092, -0.0090]	[-0.0405, -0.0376]	[-0.0373, -0.0317]	[-0.0282, -0.0250]
$Invt_{t-1}/K_{t-2}$	-0.0177	-0.0206	-0.0187			
	[-0.0178, -0.0176]	[-0.0207, -0.0204]	[-0.0188, -0.0186]			
$Constant$	0.0047	0.0046	0.0030	0.0199	0.0123	0.0213
	[0.0047, 0.0048]	[0.0046, 0.0047]	[0.0030, 0.0030]	[0.0199, 0.0200]	[0.0122, 0.0124]	[0.0212, 0.0213]
Observations	430,800	97,326	430,800	430,800	97,326	430,800
$Adj.R^2$	0.524	0.571	0.504	0.185	0.328	0.174

Table 8: **Regressions on Lagged Sales Growth with Simulated Data**

This table reports the regression results on the simulated data. The dependent variables $InvtGrowth$ and $Investment$ are defined in Table 2. FC is defined in Table 5. $SalesGrowth^{+}_{t-1}$ is the interaction of $SalesGrowth_{t-1}$ and an indicator which equals to 1 if $SalesGrowth_{t-1}$ is positive, and 0 otherwise. $SalesGrowth^{-}_{t-1}$ is the interaction of $SalesGrowth_{t-1}$ and an indicator which equals to 1 if $SalesGrowth_{t-1}$ is negative, and 0 otherwise. $SalesGrowth^{+}_{t-1} \times FC$ and $SalesGrowth^{-}_{t-1} \times FC$ are the interactions of $SalesGrowth^{+}_{t-1}$ with FC and $SalesGrowth^{-}_{t-1}$ with FC, respectively. $Below_{t-2}$ is a dummy that equals to 1 if $SalesGrowth_{t-2}$ is below the 10th percentile of the firms' distribution. $Below_{t-2} \times FC$ is $Below_{t-2}$ interacted with FC. CF_{t-2}/K_{t-3} is the two-period-lagged cash flow-to-capital ratio. $CF_{t-2}/K_{t-3} \times FC$ is CF_{t-2}/K_{t-3} interacted with FC. $Invt_{t-1}/K_{t-2}$ is the lagged inventory-to-capital ratio. The reported estimates are the cross-simulation average of the coefficients from 100 simulations. 95% confidence intervals are included in brackets. All the confidence intervals do not span zero.

	Baseline	With Exit	Cubic Cost	Baseline	With Exit	Cubic Cost
	(1)	(2)	(3)	(4)	(5)	(6)
	$InvtGrowth$	$InvtGrowth$	$InvtGrowth$	$Investment$	$Investment$	$Investment$
FC	0.0065	0.0080	0.0044	0.0054	0.0053	0.0047
	[0.0065, 0.0065]	[0.0079, 0.0080]	[0.0043, 0.0044]	[0.0053, 0.0055]	[0.0052, 0.0054]	[0.0046, 0.0048]
$SalesGrowth^{+}_{t-1}$	0.0963	0.1013	0.0411	0.0982	0.0949	0.0690
	[0.0960, 0.0966]	[0.1007, 0.1018]	[0.0408, 0.0413]	[0.0978, 0.0985]	[0.0943, 0.0955]	[0.0686, 0.0694]
$SalesGrowth^{+}_{t-1} \times FC$	-0.0324	-0.0187	0.0180	-0.0194	-0.0587	-0.0035
	[-0.0328, -0.0320]	[-0.0196, -0.0177]	[0.0177, 0.0183]	[-0.0207, -0.0182]	[-0.0600, -0.0575]	[-0.0045, -0.0025]
$SalesGrowth^{-}_{t-1}$	0.0473	0.0480	0.1097	0.0314	0.0176	0.0507
	[0.0470, 0.0476]	[0.0474, 0.0486]	[0.1093, 0.1101]	[0.0309, 0.0318]	[0.0169, 0.0183]	[0.0501, 0.0512]
$SalesGrowth^{-}_{t-1} \times FC$	0.1287	0.1565	0.0776	0.1136	0.1209	0.1122
	[0.1280, 0.1293]	[0.1550, 0.1581]	[0.1550, 0.1581]	[0.1125, 0.1147]	[0.1199, 0.1220]	[0.1111, 0.1133]
$Below_{t-2}$	0.0009	0.0015	0.0010	-0.0030	0.0001	-0.0011
	[0.0009, 0.0010]	[0.0015, 0.0016]	[0.0015, 0.0016]	[-0.0030. -0.0029]	0.000014, 0.0001]	[-0.0011, -0.0010]
$Below_{t-2} \times FC$	-0.0101	-0.0105	-0.0087	-0.0114	-0.0082	-0.0118
	[-0.0101, -0.0101]	[-0.0106, -0.0105]	[-0.0106, -0.0105]	[-0.0114, -0.0113]	[-0.0083, -0.0081]	[-0.0119, -0.0117]
CF_{t-2}/K_{t-3}	-0.0048	0.0020	-0.0050	0.0535	0.0891	0.0415
	[-0.0049, -0.0048]	[0.0018, 0.0021]	[0.0018, 0.0021]	[0.0532, 0.0538]	[0.0887, 0.0895]	[0.0412, 0.0418]
$CF_{t-2}/K_{t-3} \times FC$	0.0025	-0.0118	0.0047	-0.0350	-0.0306	-0.0243
	[0.0024, 0.0027]	[-0.0122, -0.0115]	[-0.0122, -0.0115]	[-0.0360, -0.0340]	[-0.0312, -0.0299]	[-0.0254, -0.0232]
$Invt_{t-1}/K_{t-2}$	-0.0224	-0.0302	-0.0257			
	[-0.0225, -0.0223]	[-0.0304, -0.0299]	[-0.0304, -0.0299]			
$Constant$	0.0036	0.0037	0.0065	0.0204	0.0131	0.0216
	[0.0036, 0.0036]	[0.0036, 0.0037]	[0.0036, 0.0037]	[0.0204, 0.0204]	[0.0131, 0.0132]	[0.0216, 0.0216]
Observations	430,200	98,219	430,200	430,200	98,219	430,200
$Adj.R^2$	0.082	0.083	0.077	0.151	0.263	0.142

Table 9: **Inventory Regressions with Real Data**

This table presents the results on actual data. The dependent variable *InvtGrowth* is defined in Table 2. All the independent variables are defined in Table 7. We run the regression for each quarter to account for seasonality. The regression model is estimated with firm-fixed effect. t-statistics in parentheses are adjusted using the Huber-White estimator allowing within firm clusters to avoid potential heteroskedasticity and serial correlation. Coefficients significant at the 10%, 5%, and 1% levels are marked with *, **, and ***, respectively.

	(1) Q1 $InvtGrowth$	(2) Q2 $InvtGrowth$	(3) Q3 $InvtGrowth$	(4) Q4 $InvtGrowth$
FC_t	0.0122***	0.0143***	0.00884***	0.0223***
	(4.69)	(5.08)	(3.71)	(8.55)
$SalesGrowth_t^+$	0.119***	0.168***	0.213***	0.0763***
	(6.63)	(7.45)	(10.41)	(6.00)
$SalesGrowth_t^+ \times FC_t$	-0.0398**	-0.0794***	-0.133***	-0.00625
	(-2.58)	(-3.04)	(-5.65)	(-0.48)
$SalesGrowth_t^-$	-0.0617***	0.0415**	-0.00615	-0.00729
	(-3.23)	(2.27)	(-0.39)	(-0.28)
$SalesGrowth_t^- \times FC_t$	0.0537**	-0.0302	0.0182	-0.00264
	(2.43)	(-1.42)	(0.97)	(-0.09)
$Below_{t-1}$	-0.00288***	-0.000530	-0.00434***	0.00107
	(-3.21)	(-0.72)	(-3.39)	(1.46)
$Below_{t-1} \times FC_t$	-0.00241**	-0.00228*	-0.00150	-0.00596***
	(-2.11)	(-1.86)	(-0.93)	(-4.21)
CF_{t-1}/K_{t-2}	0.186***	0.267***	0.265***	0.229***
	(8.39)	(10.42)	(7.74)	(8.90)
$CF_{t-1}/K_{t-2} \times FC_t$	-0.0504*	-0.0769**	-0.108***	-0.0595*
	(-1.74)	(-2.61)	(-3.02)	(-1.78)
$Invt_{t-1}/K_{t-2}$	-0.0244***	-0.0286***	-0.0192***	-0.0544***
	(-6.05)	(-7.29)	(-4.68)	(-19.93)
$Constant$	-0.000300	-0.00494***	-0.00117	-0.00657***
	(-0.19)	(-2.91)	(-0.73)	(-4.00)
Observations	59,895	60,786	59,776	59,437
$Adj.R^2$	0.330	0.280	0.396	0.438

Table 10: **Inventory Regressions on Lagged Sales Growth with Real Data**

This table presents the results on actual data. The dependent variable *InvtGrowth* is defined in Table 2. All the independent variables are defined in Table 8. We run the regression for each quarter to account for seasonality. The regression model is estimated with firm-fixed effect. t-statistics in parentheses are adjusted using the Huber-White estimator allowing within firm clusters to avoid potential heteroskedasticity and serial correlation. Coefficients significant at the 10%, 5%, and 1% levels are marked with *, **, and ***, respectively.

	(1) Q1 $InvtGrowth$	(2) Q2 $InvtGrowth$	(3) Q3 $InvtGrowth$	(4) Q4 $InvtGrowth$
FC_t	0.0143***	0.0113***	0.00956***	0.0233***
	(4.66)	(4.83)	(3.97)	(7.93)
$SalesGrowth^+_{t-1}$	0.111***	0.0461***	0.154***	0.0950***
	(7.68)	(3.36)	(9.84)	(5.91)
$SalesGrowth^+_{t-1} \times FC_t$	-0.0464**	0.0225	-0.0859***	-0.0330
	(-2.25)	(1.16)	(-5.36)	(-1.66)
$SalesGrowth^-_{t-1}$	-0.0166	0.00835	0.00569	-0.0257
	(-0.78)	(0.55)	(0.24)	(-1.57)
$SalesGrowth^-_{t-1} \times FC_t$	0.0801***	0.0304*	0.0592**	0.0606***
	(3.40)	(1.93)	(2.31)	(3.15)
$Below_{t-2}$	-0.00185**	-0.000425	0.00164**	-0.0000268
	(-2.52)	(-0.49)	(2.38)	(-0.03)
$Below_{t-2} \times FC_t$	-0.00198	-0.00460***	-0.00227	-0.00416***
	(-1.36)	(-3.30)	(-1.52)	(-3.09)
CF_{t-2}/K_{t-3}	0.224***	0.160***	0.210***	0.213***
	(6.04)	(7.76)	(6.99)	(7.30)
$CF_{t-2}/K_{t-3} \times FC_t$	-0.0906**	-0.0353	-0.0745**	-0.0878***
	(-2.22)	(-1.42)	(-2.35)	(-2.88)
$Invt_{t-1}/K_{t-2}$	-0.0264***	-0.0212***	-0.0179***	-0.0520***
	(-6.59)	(-5.50)	(-4.12)	(-17.55)
$Constant$	-0.00119	-0.000117	-0.000728	-0.00617***
	(-0.60)	(-0.08)	(-0.46)	(-3.60)
Observations	58,189	58,747	57,870	58,380
$Adj.R^2$	0.334	0.261	0.388	0.437

Table 11: **Investment Regressions with Real Data**

This table reports the results on actual data. The dependent variable *Capex* and *PPEGrowth* are defined in Table 2. All the independent variables are defined in Table 7. We run the regression for each quarter to account for seasonality. The regression model is estimated with firm-fixed effect. t-statistics in parentheses are adjusted using the Huber-White estimator allowing within firm clusters to avoid potential heteroskedasticity and serial correlation. Coefficients significant at the 10%, 5%, and 1% levels are marked with *, **, and ***, respectively.

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	$Capex$	$Capex$	$Capex$	$Capex$	$PPEGrowth$	$PPEGrowth$	$PPEGrowth$	$PPEGrowth$
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FC_t	0.0120***	0.0142***	0.0153***	0.0121***	0.0145***	0.0177***	0.0215***	0.0212***
	(6.80)	(8.14)	(10.78)	(8.53)	(5.69)	(7.55)	(8.77)	(9.63)
$SalesGrowth_t^+$	0.0334***	0.0427***	0.0519***	0.0531***	0.157***	0.149***	0.191***	0.143***
	(7.06)	(9.93)	(12.80)	(12.96)	(11.42)	(11.86)	(16.07)	(13.28)
$SalesGrowth_t^+ \times FC_t$	-0.00130	-0.0102*	-0.0210***	-0.0264***	-0.0705***	-0.0794***	-0.108***	-0.0664***
	(-0.22)	(-1.94)	(-4.08)	(-5.58)	(-5.40)	(-6.59)	(-9.53)	(-5.07)
$SalesGrowth_t^-$	-0.00833***	-0.0130**	-0.0114*	-0.0150**	0.0212***	0.0127	0.0301**	0.0252**
	(-3.04)	(-2.23)	(-1.94)	(-2.36)	(3.00)	(1.13)	(2.70)	(2.32)
$SalesGrowth_t^- \times FC_t$	0.0125**	0.0217***	0.0203***	0.0271***	-0.00700	0.00280	-0.0142	-0.00215
	(2.69)	(3.68)	(3.17)	(3.63)	(-0.82)	(0.23)	(-1.35)	(-0.19)
$Below_{t-1}$	0.000451	0.000379	0.00109	0.00205***	-0.00221	-0.00279***	-0.000885	0.000747
	(0.65)	(0.75)	(1.66)	(3.57)	(-1.49)	(-5.91)	(-0.61)	(0.66)
$Below_{t-1} \times FC_t$	-0.00143**	-0.000433	-0.00126	-0.00323***	0.000658	0.00136*	-0.00108	-0.00129
	(-2.63)	(-0.88)	(-1.48)	(-5.57)	(0.47)	(1.69)	(-0.58)	(-0.84)
CF_{t-1}/K_{t-2}	0.0654***	0.124***	0.120***	0.106***	0.101***	0.169***	0.160***	0.172***
	(12.49)	(12.48)	(12.36)	(9.13)	(15.34)	(8.06)	(12.67)	(8.70)
$CF_{t-1}/K_{t-2} \times FC_t$	-0.0245***	-0.0721***	-0.0689***	-0.0545***	-0.0276***	-0.0686***	-0.0669***	-0.0632***
	(-8.67)	(-7.99)	(-8.03)	(-5.83)	(-3.70)	(-3.40)	(-6.43)	(-3.70)
$Constant$	0.0110***	0.0103***	0.0100***	0.0132***	-0.00765***	-0.00997***	-0.0111***	-0.0108***
	(11.42)	(10.33)	(11.88)	(14.42)	(-5.64)	(-7.21)	(-7.68)	(-7.80)
Observations	52,154	52,204	51,177	50,747	59,649	60,526	59,512	59,178
$Adj.R^2$	0.383	0.382	0.399	0.386	0.128	0.134	0.148	0.137

Table 12: **Investment Regressions on Lagged Sales Growth with Real Data**

This table reports the results on actual data. The dependent variable *Capex* and *PPEGrowth* are defined in Table 2. All the independent variables are defined in Table 8. We run the regression for each quarter to account for seasonality. The regression model is estimated with firm-fixed effect. t-statistics in parentheses are adjusted using the Huber-White estimator allowing within firm clusters to avoid potential heteroskedasticity and serial correlation. Coefficients significant at the 10%, 5%, and 1% levels are marked with *, **, and ***, respectively.

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	Capex	*Capex*	*Capex*	*Capex*	*PPEGrowth*	*PPEGrowth*	*PPEGrowth*	*PPEGrowth*
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FC_t	0.0126***	0.0121***	0.0146***	0.0117***	0.0143***	0.0152***	0.0209***	0.0210***
	(7.47)	(7.22)	(9.92)	(6.26)	(4.98)	(6.31)	(8.45)	(7.75)
$SalesGrowth^+_{t-1}$	0.0196***	0.0222***	0.0306***	0.0340***	0.0130**	0.0289***	0.0426***	0.0377***
	(7.61)	(4.94)	(6.84)	(7.32)	(2.71)	(3.56)	(6.55)	(4.67)
$SalesGrowth^+_{t-1} \times FC_t$	-0.00377	-0.00179	-0.00681	-0.0168***	0.00298	-0.00157	-0.00606	-0.0128*
	(-1.11)	(-0.33)	(-1.31)	(-3.56)	(0.45)	(-0.18)	(-0.92)	(-1.73)
$SalesGrowth^-_{t-1} \times FC_t$	-0.000644	-0.0127***	-0.0107***	-0.0170***	0.0132	0.0198***	0.000205	-0.00663
	(-0.12)	(-3.88)	(-3.02)	(-3.62)	(1.02)	(3.17)	(0.02)	(-0.57)
$SalesGrowth^-_{t-1} \times FC_t$	0.00483	0.0172***	0.0163***	0.0246***	0.00210	0.00194	0.00907	0.0141
	(0.88)	(4.40)	(3.42)	(4.37)	(0.16)	(0.25)	(0.71)	(1.04)
$Below_{t-2}$	0.000759*	0.000319	0.000601	0.00136*	0.00102	0.00117	-0.000957*	0.00137
	(1.73)	(0.36)	(1.25)	(1.93)	(0.97)	(1.24)	(-1.72)	(0.78)
$Below_{t-2} \times FC_t$	-0.00106	-0.000666	-0.000525	-0.00218**	-0.00157	-0.00234**	0.000651	-0.00133
	(-1.64)	(-0.95)	(-0.91)	(-2.51)	(-1.15)	(-2.06)	(0.67)	(-0.69)
CF_{t-2}/K_{t-3}	0.0958***	0.0811***	0.135***	0.135***	0.128***	0.124***	0.167***	0.223***
	(10.72)	(13.58)	(12.28)	(12.77)	(10.45)	(10.92)	(9.93)	(11.63)
$CF_{t-2}/K_{t-3} \times FC_t$	-0.0428***	-0.0368***	-0.0788***	-0.0819***	-0.0358***	-0.0473***	-0.0664***	-0.118***
	(-6.65)	(-8.29)	(-8.37)	(-8.33)	(-3.11)	(-4.35)	(-4.05)	(-7.33)
$Constant$	0.0101***	0.0124***	0.0102***	0.0135***	-0.00696***	-0.00518***	-0.00923***	-0.00895***
	(10.84)	(12.50)	(12.67)	(13.07)	(-4.17)	(-3.84)	(-6.29)	(-5.88)
Observations	50,950	50,914	49,802	49,940	57,947	58,503	57,624	58.121
$Adj.R^2$	0.384	0.379	0.395	0.388	0.106	0.107	0.121	0.117

Table 13: **Sales Shocks and Cumulative Inventory Growth**

This table presents the effects of sales shocks on cumulative inventory growth. Column (1) is with simulated data and Column (2) is with actual data. The dependent variable $InvtGrowth$ is defined in Table 2. $Above_{t-k}$ is a dummy that equals to 1 if $SalesGrowth_{t-k}$ is above the 90th percentile of the firms' distribution. $Below_{t-k}$ is a dummy that equals to 1 if $SalesGrowth_{t-k}$ is below the 10th percentile. $Above_{t-k} \times FC$ and $Below_{t-k} \times FC$ are the interactions of FC with $Above_{t-k}$ and $Below_{t-k}$, respectively. We include up to 6 lags in the regression. All the other independent variables are defined in Table 8. We sum up the coefficients of $Above_{t-1}$ up to $Above_{t-6}$ as $\sum_{k=1}^{6} Above_{t-k}$, and $Below_{t-1}$ up to $Below_{t-6}$ as $\sum_{k=1}^{6} Below_{t-k}$.The interactions are also added up to form $\sum_{k=1}^{6} Above_{t-k} \times FC$ and $\sum_{k=1}^{6} Below_{t-k} \times FC$. With Simulated data, we run the regression on 100 simulated panels. The reported estimates are the cross-simulation averages. 95% confidence intervals are included in brackets. All the confidence intervals do not span zero. With real data, we run the regression for each quarter to account for seasonality. The regression model is estimated with firm-fixed effect. The reported coefficients are the average over the four quarters. t-statistics in parentheses are calculated using the Fama-MacBeth method. Coefficients significant at the 10%, 5%, and 1% levels are marked with *, **, and ***, respectively.

	Simulated Data	Real Data
	(1)	(2)
	$InvtGrowth$	$InvtGrowth$
FC	0.0029	0.0167***
	[0.0029, 0.0030]	(7.50)
$SalesGrowth_t^+$	0.2385	0.1382**
	[0.2383, 0.2387]	(5.35)
$SalesGrowth_t^+ \times FC$	-0.1378	-0.0702*
	[-0.1383, -0.1373]	(-3.15)
$SalesGrowth_t^-$	0.3415	0.0042
	[0.3413, 0.3418]	(0.21)
$SalesGrowth_t^- \times FC$	0.0289	0.0055
	[0.0277, 0.0301]	(0.32)
$\sum_{k=1}^{6} Above_{t-k}$	0.0095	0.0059*
	[0.0095, 0.0095]	(3.12)
$\sum_{k=1}^{6} Above_{t-k} \times FC$	0.0299	0.0107***
	[0.0298, 0.0300]	(4.53)
$\sum_{k=1}^{6} Below_{t-k}$	-0.0002	-0.0079**
	[-0.0003, -0.0002]	(-4.21)
$\sum_{k=1}^{6} Below_{t-k} \times FC$	-0.0206	-0.0087*
	[-0.0207, -0.0205]	(-2.57)
CF_{t-1}/K_{t-2}	0.0039	0.224***
	[0.0039, 0.0039]	(10.83)
$CF_{t-1}/K_{t-2} \times FC$	-0.0053	-0.075***
	[-0.0055, -0.0052]	(-6.03)
$Invt_{t-1}/K_{t-2}$	-0.0139	-0.0185
	[-0.0140, -0.0139]	(-1.44)
$Invt_{t-1}/K_{t-2} \times FC$	0.0096	-0.0241*
	[0.0095, 0.0098]	(-2.67)
$Constant$	0.0030	-0.0043**
	[0.0030, 0.0030]	(-3.74)
Observations	428,400	52,545
$Adj.R^2$	0.564	0.373