Corporate Cash and Inventory Management: Implications for Measuring Market Competition

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Abstract

In this paper I study the tradeoff between cash and inventory in the presence of productivity uncertainty and costly external financing, and show that the degree of product market competition (captured by the elasticity of substitution between differentiated goods) is a crucial determinant of firms' cash and inventory policies. I develop an industry equilibrium model to understand this tradeoff. In the model, individual firms operate in a monopolistically competitive market with some degree of pricing power and are subject to idiosyncratic productivity shocks. Firms hold inventory to prevent stock-outs and accumulate internal resources (cash and/or inventory) to finance their operation. Cash is liquid but earns a low and constant return. Inventory can be converted into cash whenever necessary, yet is subject to product market conditions. I show that inventory is particularly valuable for firms that have a high degree of control over prices. The presence of inventory however reduces the value of holding cash. As a result, firms with greater pricing power hold more inventory and less cash relative to firms having lower pricing power. Exploiting this model implication, I infer the degree of market competition for manufacturing sector from its cash and inventory behavior. The estimated model behaves consistently with data. Lastly, using the model as a laboratory, I conduct an experiment to evaluate the effect of an intensified market competition. I find that a 5% drop in markup prompts firms to cut inventory holdings by 3.3% and raise cash balance by 1.1%.

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1 Introduction

Cash and inventory are two crucial components of firms' assets.[1] The former hedges against adverse liquidity shocks and facilitates firms' daily operation including inventory investment. The latter provides protection for firms against product-market uncertainty. Insufficient inventory can result in lost internal cash resources from lost sales, while excessive inventory locks up resources in an inefficient manner and can place a heavy financial burden on firms. As a result, cash and investment management are closely intertwined and not supposed to be decoupled from each other and analyzed in isolation. This is especially true in the presence of financial frictions.

Although empirical studies in corporate finance link cash and inventory together by including working capital net of cash as an explanatory variable in cash regressions (see for example, Opler et al. (1999) and Bates et al. (2009)), almost nothing is known regarding the resource allocation choices between these two margins. This paper contributes to the literature by providing theoretical foundation and empirical support for the cash-inventory tradeoff.

In this paper I investigate how firms manage cash and inventory jointly. I first use a three-period static model characterized by uncertainty and imperfect capital markets to show that product market competition is one of the critical determinants of the tradeoff between cash and inventory holdings. More specifically, I set up a model in which a risk-neutral firm operates in a monopolistically competitive market with some degree of pricing power and faces stochastic productivity shocks. To prevent lost sales due to stock-outs, the firm holds inventory. In addition, the firm faces a fixed cost, which can be paid through three channels: cash flows generated from selling inventory and newly-produced goods, cash holdings and external equity. The capital market is assumed to be imperfect and modelled by equity issuance costs. To avoid raising expensive external funds, the firm attempts to meet liquidity needs by holding inventory and/or freeing up resources from inventory and saving them as cash. In this model, the firm holds inventory to avoid future stock-outs (see for example, Bils and Kahn (2000)) and to mitigate costs of financial stress (see for example, Carpenter et al. (1994) and Choi and Kim (2001)) and accumulates cash to meet liquidity needs (see for example, Riddick and Whited (2009)). Cash earns a low and constant return, while inventory earns a return contingent on the future state of the world and the firm's pricing power.

How do firms allocate resources between cash and inventory when they face the tradeoff described above? My model implies that the choice between these two margins depends largely on product market competition, namely the elasticity of substitution between differentiated goods or the price elasticity of demand that firms face.[2] Firms in less competitive market enjoy greater

[1] They account for 60% of total current assets and 33% of total assets for U.S. non-financial, non-utility publicly traded firms in 2009, with both ratios staying roughly constant over the last four decades.

[2] Note that the degree of market competition in this paper is captured by the elasticity of substitution between differentiated goods, which is equal to the price elasticity of demand under model assumptions. Hence in this paper the terms "price elasticity of demand" and "elasticity of substitution" are interchangeable.

pricing power and place more weight on inventory relative to cash. The intuition for the result is as follows. When facing relatively inelastic demand, firms are able to charge a higher product price without losing customers in good states of the world, which in turn yields a higher expected return from holding inventory. Moreover, the ability to charge higher product prices over marginal costs implies that firms are less likely to face financial difficulties and have lower incentive to hold cash. As demand becomes more responsive to prices, both the profit and the prospect of gaining from holding inventory drop. Firms then start reducing inventory and raising cash to preserve financial flexibility. As a result, firms facing less elastic demand allocate more resources in inventory than those facing more elastic demand.

To analyze this tradeoff in a quantitative manner, I relax the restrictions imposed in the three-period model and extend it to a dynamic industrial equilibrium. The results of comparative statics confirm the crucial role of product market competition in determining firms' cash and inventory policies. I next use the model to estimate the degree of product market competition in the U.S. manufacturing sector by extracting information from its cash and inventory behavior. The estimated model successfully replicates a number of empirical regularities. Lastly, I use the model as a laboratory to assess the effect of increased market competition on cash and inventory choices. I find that in response to a 5% drop in markup due to an increase in product substitutability, cash will increase by 1.1%, and inventory will decline by 3.3%, accompanied by a substantial heterogeneity across firms.

This paper contributes to the literature in several ways. First, it studies working capital management by putting cash and inventory within a unified framework and exploring the interaction between them. Most previous work analyzes cash and inventory policies separately. Each of the two parallel streams of studies offers an incomplete picture of firms' working capital management. As cash and inventory decisions are closely linked to each other, studying them jointly helps to generate important insight neglected in the literature. Gao (2014) and Kulchania and Thomas (2014) also examine the relationship between cash and inventory and focus on their over-time dynamics. However, unlike those two studies, this paper aims to understand cross-sectional differences and proposes a complementary explanation that underlies the relationship.

Second, this paper helps to understand the effect of market competition on cash holdings both theoretically and empirically. Morellec et al. (2014) and Della Seta (2011) suggest that market competition increases the option value of remaining active in the market and therefore firms hold cash to avoid inefficient closure. My paper distinguishes itself from those two studies by presenting a different mechanism through which market competition shapes cash policy. My model suggests that increased market competition limits firms' pricing ability and in turn reduces firms' profitability. This affects cash holdings through two channels: first, it lowers cash flows and increases needs for internal buffers; second, it lowers the return on inventory and in turn makes cash more valuable when liquidity is needed. Hence, as the product market becomes more competitive, firms carry more cash. Furthermore, I use my model to do quantitative analysis and evaluate the impact of increased market competition.

Lastly, this paper contributes to the literature by providing an estimate of the elasticity of substitution between differentiated goods. This structural parameter has important implications for the benefits of price adjustment and therefore for the degree of monetary non-neutrality, which is central from both academic perspective and monetary policy perspective. However, there is no clear consensus in the literature regarding its value. Golosov and Lucas (2007) set the elasticity of substitution to be 7. Devereux and Siu (2007) select a value over 10. Nakamura and Steinsson (2010) set it equal to 4, whereas Midrigan (2011) chooses 3. This paper infers its value from firms' cash and inventory choices.

The remainder of the paper is structured as follows. Section 2 presents a simple three-period model to highlight the main mechanism that underlies the inventory-cash tradeoff. Section 3 describes an industrial equilibrium model and Section 4 reports the estimation results. Section 5 concludes.

2 A Simple Three-Period Model

In this section, I consider a static model that builds upon Palazzo (2012) by incorporating pricing power and inventory holdings.[3] I then use the model to illustrate the main ideas behind the tradeoff between cash and inventory.

2.1 Structure

The model has three periods, denoted by $t = 1$, 2 and 3. At period 1 and 2, a firm is endowed with $w_1 = 1$ units and e^z units of goods, respectively. The productivity shock z is unknown at period 1. It has a normal distribution with mean μ and variance σ^2, $z \sim N(\mu, \sigma^2)$. At period 2, after the realization of z, the firm faces an investment opportunity that costs $I = 1$. This investment opportunity allows the firm to invest in a risk-free asset. That risk-free asset produces w_3 units of goods at period 3. I assume that w_3 is so large that the firm chooses to invest at period 2 with probability 1. The good is divisible.

The firm pays I out of either internal or external funds or a combination of both. The firm has two instruments to transfer resources internally from period 1 to period 2. One is to save cash out of cash flows. This option earns a gross rate of return $\hat{R} > 1$, which is lower than the gross risk-free rate. The alternative is to carry inventory forward. Inventory depreciates at the end of period 1 at a rate δ, $0 < \delta < 1$, and can be sold to generate cash flows in period 2. If the firm has insufficient internal resources to finance the investment at period 2, it can borrow externally at rate λ by issuing equity.

[3] See, also, Kim et al. (1998).

The firm operates in a monopolistically competitive market and faces a demand function with a constant price elasticity θ, $\theta > 1$:

$$q = (\frac{p}{P})^{-\theta} Q.$$

The variable p denotes the price charged by the firm, q is the quantity demanded, while P and Q are industry price and quantity. In this three-period partial equilibrium model, the firm solves its problem given industry price and quantity, $P = 1$ and $Q = 1$. I will relax these restrictions in next section and consider a firm's problem within the context of an industry equilibrium.

The parameter θ controls the degree of substitutability among products available in the market. Changes in θ therefore indicate changes in the degree of market competition. The lower the θ, the greater the pricing power of firms and the less competitive the market is as a whole. To focus on the main tradeoff, I assume that the firm only sets price in period 1, given the endowment level w_1. The unsold goods are stored as inventory and carried forward to period 2. At period 2, all goods must be sold. Therefore, the price at period 2 is no longer a choice variable, but determined by the beginning-of-period inventory holdings and the new endowment e^z. At period 3, product price is exogenous and equal to 1. Note that all these assumptions are imposed to make analysis simpler yet preserve intuitions, and will be relaxed in the dynamic model presented in next section.

2.2 Firm's Problem

At period 1, the firm allocates endowed resources into three choices, cash savings c_2, inventory s_2 and dividend payment d_1. Given the endowment w_1, the firm makes its decision on how many units of goods to sell q_1, under a constraint on the quantity of goods currently available for sale, $q_1 \leq w_1$. The unsold goods are stored as inventory, s_2. They depreciate and are transferred to period 2. The firm also decides how much cash, c_2, to save out of cash flows. The period-one dividend is given by

$$d_1 = p_1 q_1 - c_2,$$

where

$$q_1 = \min\{w_1, p_1^{-\theta}\},$$

$$p_1 = q_1^{-\frac{1}{\theta}},$$

$$c_2 \geq 0,$$

$$s_2 = (1 - \delta)(w_1 - q_1) \geq 0.$$

At period 2, the firm has an opportunity to invest in a risk-free asset which costs I. If the firm does not have sufficient internal resources to cover the cost, that is, cash savings $\hat{R}c_2$ plus the realized cash flows $p_2 q_2$ are less than I, the firm borrows externally to cover the gap. If the firm can afford the cost with the available internal resources, the remaining funds are distributed as dividends. The parameter $\hat{R}$ denotes the effective rate of return on cash savings.

$$d_2 = (1 + \lambda\phi)[p_2 q_2 + \hat{R}c_2 - I],$$

where

$$q_2 = e^z + s_2,$$
$$p_2 = q_2^{-\frac{1}{\theta}},$$
$$\phi = \begin{cases} 1 & \text{if } d_2 \leq 0, \\ 0 & \text{otherwise.} \end{cases}$$

The first constraint corresponds to the assumption that all goods must be sold at period 2. The quantity q_2 and the price p_2 therefore are determined by the shock realization z and the beginning-of-period inventory holdings s_2. The indicator function ϕ equals 1 if the firm needs to access capital markets and borrow externally, and 0 otherwise.

In the last period, the dividend distributed is the cash flows generated by the investment, w_3 units of goods valued at a price of 1:

$$d_3 = w_3.$$

The risk neutral firm's objective is to maximize the discounted expected value of future stream of dividends, by choosing optimal inventory holdings s_2 and cash savings c_2. The firm's problem can be written as follows:

$$\max_{s_2 \geq 0, c_2 \geq 0} d_1 + \beta \mathbb{E}_1 d_2 + \beta^2 \mathbb{E}_1 d_3, \tag{1}$$

where the discount factor β equals $\frac{1}{1+r}$, r is the risk-free rate, and dividends d_1, d_2 and d_3 are specified as above.

2.3 Optimal Policy Rules

In this subsection, I characterize optimal decision rules for the firm's problem and develop the intuition behind them.

2.3.1 Cash

Solving the optimization problem (1) gives the optimal cash saving policy, which satisfies

$$1 = \hat{R}\beta + \lambda \hat{R}\beta \mathbb{E}\phi + \mu_1, \tag{2}$$

where

$$\phi = \begin{cases} 1 & \text{if } d_2 \leq 0, \\ 0 & \text{otherwise.} \end{cases}$$

The left-hand side of equation (2) represents the cost of saving an extra unit of cash, that is, forgone dividends in period 1. The right-hand side of the equation is the marginal benefit of cash savings, the sum of discounted expected return (the first term) and discounted expected reduction in the cost of external borrowing (the second term). The last term on the right-hand side is the Lagrange multiplier of the nonnegativity constraint on cash and gives the shadow price of cash holdings.

2.3.2 Inventory

The optimal inventory policy, or equivalently, the firm's pricing rule is given by

$$\frac{\theta-1}{\theta}q_1^{-\frac{1}{\theta}} = (1-\delta)\beta\mathbb{E}\frac{\partial d_2}{\partial s_2} + \mu_2, \tag{3}$$

where θ is the price elasticity of demand. The left-hand side of equation (3) gives the cost of carrying one additional unit of goods forward to period 2, which is $\frac{\theta-1}{\theta}q_1^{-\frac{1}{\theta}}$ dollars of forgone revenue and thus foregone dividends in period 1. The right-hand side shows the marginal benefit, which is the expected present value of an additional unit of end-of-period inventory for period 2 after depreciation. The parameter μ_2 is the Lagrange multiplier of the nonnegativity constraint on inventory.

Substituting the demand function into equation (3), I can rewrite the optimal condition in a more familiar form. In the case of an interior solution, equation (3) becomes

$$p_1 = \frac{\theta}{\theta-1}[(1-\delta)\beta\mathbb{E}\frac{\partial d_2}{\partial s_2}]. \tag{4}$$

The above equation describes the optimal pricing rule of a monopolistically competitive firm. That is, the firm charges a constant markup over marginal cost. Here, the constant markup is $\frac{\theta}{\theta-1}$. The marginal cost is the firm's marginal value of an additional unit of inventory, $(1-\delta)\beta\mathbb{E}\frac{\partial d_2}{\partial s_2}$.

Under the assumption that all goods must be sold in period 2, equation (4) can be written as follows, which relates the price set at period 1 with the expected price that would be set at period 2,

$$\frac{\theta-1}{\theta}p_1 = (1-\delta)\beta\mathbb{E}\{\frac{\theta-1}{\theta}p_2\} + \lambda(1-\delta)\beta\mathbb{E}\{\phi\frac{\theta-1}{\theta}p_2\}. \tag{5}$$

According to equation (5), there are two motives for holding inventory in this model. The first is the stockout-avoidance motive, captured by the first term on the right-hand side of the equation. The firm makes the carrying decision based on the prospects for benefiting from a price increase as a result of supply shortage. This might happen when the firm expects a large negative productivity shock that will create an expectation of a gain from holding inventory. The second motive is to mitigate financial stress, as indicated by the second term on the right-hand side. Inventory is a reversible store of liquidity. It can be sold to generate cash flows and save expected borrowing costs, playing a similar role to cash.

2.4 Tradeoff between Cash and Inventory

As shown above, cash and inventory are valuable to firms but compete for limited resources. To understand the resource allocation choices between them, I next take a closer inspection of Euler equations. The first order condition associated with inventory is,

$$\frac{\theta-1}{\theta}q_1^{-\frac{1}{\theta}} = (1-\delta)\beta\mathbb{E}\{\frac{\theta-1}{\theta}q_2^{-\frac{1}{\theta}}\} + \lambda(1-\delta)\beta\mathbb{E}\{\phi\frac{\theta-1}{\theta}q_2^{-\frac{1}{\theta}}\} + \mu_2.$$

Consider first the limiting case in which the elasticity of demand is unity, $\theta = 1$. Then the expression becomes

$$0 \cdot q_1^{-1} = (1-\delta)\beta\mathbb{E}\{0 \cdot q_2^{-1}\} + \lambda(1-\delta)\beta\mathbb{E}\{\phi \cdot 0 \cdot q_2^{-1}\} + \mu_2.$$

As the unit-elastic demand implies that total revenue is irresponsive to changes in price, the marginal cost of carrying inventory forward to next period is always zero. Because of the non-negative shadow price of inventory, the marginal benefit of holding inventory is greater or equal to its marginal cost. Therefore, in this extreme case of unit-elastic demand, firms hold a positive level of inventory. On the other hand, the marginal benefit of holding cash in this case is lower than the marginal cost. This result follows from the zero marginal cost of carrying inventory and hence zero probability of being financially constrained, $\mathbb{E}\phi = 0$. That is, firms can always hold inventory as buffers for internal finance without incurring any costs. Therefore in the case of unit-elastic demand firms hold zero cash balances.

An increase in the price elasticity of demand has impacts on the return of holding cash and inventory. Consider another extreme case in which firms face perfectly elastic demand, $\theta \to \infty$. The first order condition of inventory becomes

$$1 \cdot q_1^0 = (1-\delta)\beta\mathbb{E}\{1 \cdot q_2^0\} + \lambda(1-\delta)\beta\mathbb{E}\{\phi \cdot 1 \cdot q_2^0\} + \mu_2 = (1-\delta)\beta\mathbb{E}\{1+\phi\lambda\} + \mu_2. \tag{6}$$

In this case, firms are price takers, and product price is constant across periods. Therefore the expected gain from price changes is zero. Firms hold inventory only when the benefit from the expected reduction in borrowing costs dominates the losses associated with depreciation. Relative to inventory, cash is more valuable in this case, as can be seen from the optimal condition for cash,

$$1 = \beta\hat{R}\mathbb{E}(1+\phi\lambda) + \mu_1. \tag{7}$$

Given the same marginal cost of holding cash and inventory, the additional dollar of cash savings is valued at the rate of $\hat{R}\mathbb{E}(1+\phi\lambda)$ which is greater than the return on inventory, $(1-\delta)\mathbb{E}(1+\phi\lambda)$. As a result, in the case of perfectly elastic demand, cash is preferred to inventory.

The above discussion of two limiting cases provides a flavor that firms' cash and inventory decisions depend on the degree of product market competition (i.e. the price elasticity of demand). More specifically, firms' cash to inventory ratio increases with the price elasticity of demand. When the elasticity is low, firms are able to set a high price over cost and more importantly, to transfer goods across time without lowering future prices significantly. Therefore, they have high gross margins and a high return on holding inventory. The presence of inventory reduces the value of cash, as firms can sell inventory to generate cash flows and mitigate financial distress. As demand becomes more elastic, both the profit and the prospect of gaining from holding inventory drop. Firms then start freeing up resources tied up in inventory and saving them as cash to preserve financial flexibility.

The effect of θ on cash and inventory policies is illustrated in the upper left panel of Figure 1. An increase in θ leads firms to reallocate resources from inventory to cash. As θ increases, the demand function becomes flatter, and the degree of responsiveness in demand quantity with respect to price rises. Firm therefore have lower pricing power and are more likely to experience a cash flow shortfall. In response to this situation, firms choose to gradually free up cash from inventory.

Besides the degree of market competition (θ), firms' cash and inventory tradeoff also depends on other variables, including inventory carrying costs (δ), the effective return on cash holdings ($\hat{R}$), the mean of productivity shock (μ), the standard deviation of productivity shock (σ) and the risk-free rate (r). Figure 1 provides a graphical description of the impacts.

A higher inventory carrying cost, δ, makes it more expensive to hold inventory. As a result, firms choose to transfer less inventory but more cash over periods to meet future liquidity needs. Similarly, a rise in the effective rate of return on cash, $\hat{R}$, drives up the value of cash savings in each state of the world. Firms therefore shift resources from inventory to cash, as shown in the middle left panel.

The middle right panel of Figure 1 illustrates the effect of the expected future supply (captured by the mean of productivity shock μ) on the cash and inventory decisions. The larger the mean value of productivity shocks, the higher a cash flow is expected to arrive in the future, and also less likely firms will need to borrow externally. Accordingly, firms have a weaker incentive to accumulate internal funds and choose to reduce both inventory and cash holdings. In addition, an increase in the mean value of future supply drives down the expected price and in turn the value of inventory. Firms thus cut inventory holdings even further.

The impact of uncertainty σ is shown in the lower left panel of Figure 1. An increase in σ results in simultaneous rises in cash and inventory holdings. Intuitively, as the productivity shock becomes more volatile, firms are more likely to experience low productivity states. They therefore

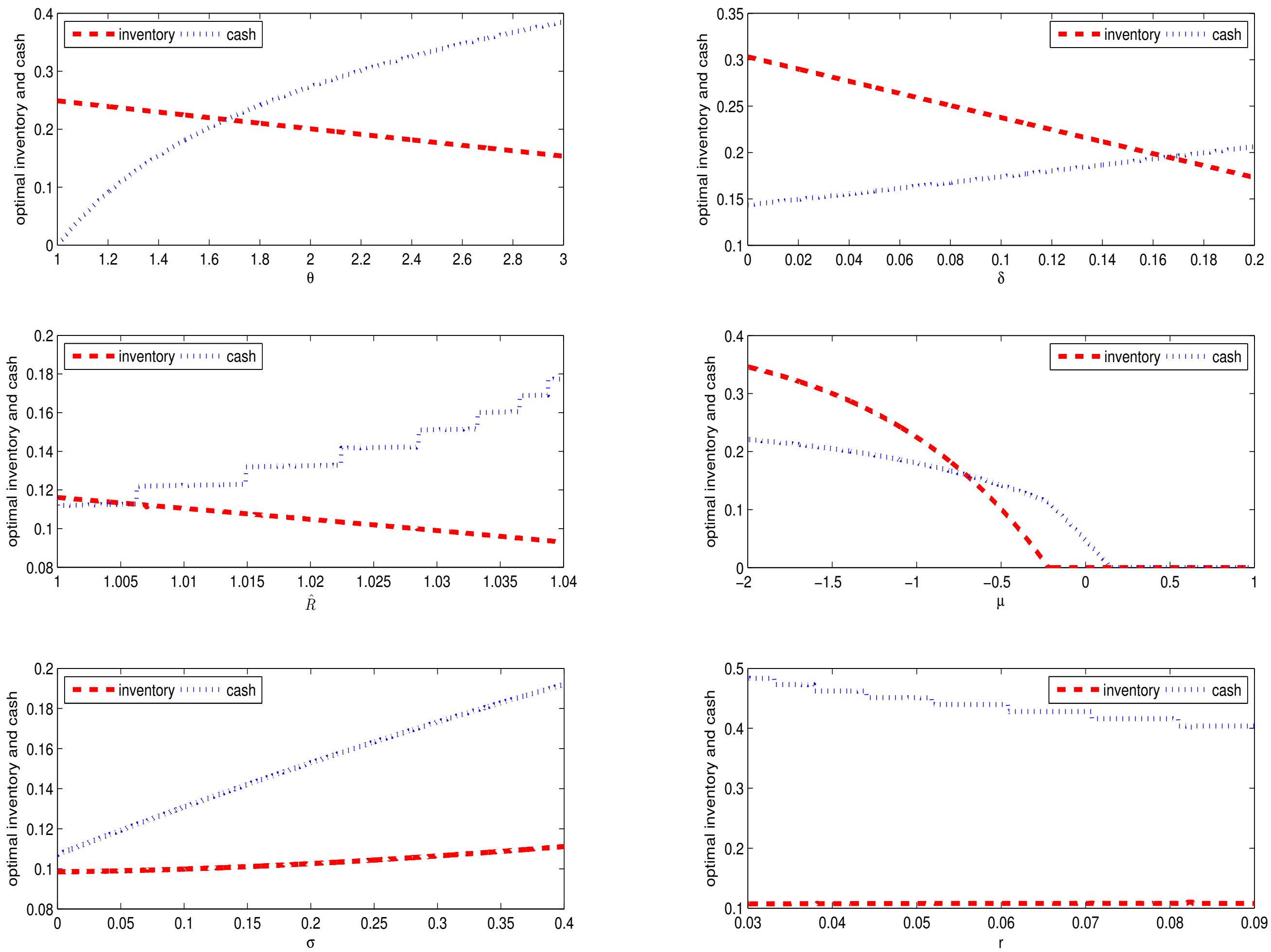


Figure 1: **Comparative Statics of a Simple Three-period Model.** This figure illustrates the impacts of product market competition θ (the top left panel), inventory carrying costs δ (the top right panel), the effective return on cash $\hat{R}$ (the middle left panel), the expected future productivity μ (the middle right panel), the volatility of productivity shocks σ (the bottom left panel) and the risk-free rate r (the bottom right panel) on the optimal cash and inventory holdings.

increase inventory holdings to avoid stock-outs. Moreover, an increase in shock volatility raises the likelihood of being financially constrained. To avoid raising costly external funds, firms choose to accumulate more internal resources.

The last panel plots the effect of risk-free rate r. Cash balance declines with r given its constant effective rate of return $\hat{R}$, while inventory is irresponsive to r. The risk-free rate represents the opportunity cost. As the risk-free rate increases, the cost of holding cash increases. Firms therefore lower their cash savings. The irresponsiveness of inventory to interest rates is surprising at first sight, as common sense and traditional theory predict a negative relationship. The insensitivity of inventory in this model arises from firms' pricing power. An increase in risk-free rate depresses the marginal value of inventory in the subsequent period. Firms therefore charge a lower price at current period, given the pricing rule shown in equation (4). The reduced current price drives up the expected return on holding inventory and completely offsets the direct effect of the increase in risk-free rate, which leaves the optimal inventory holdings unchanged. Introducing pricing power therefore offers a potential resolution to the long lasting puzzle in the inventory literature — the lack of empirical evidence on the relation between inventory and interest rates (see Maccini et al. (2004) for example).

All these results remain unchanged if I replace the productivity shock in the model with a demand shock. This follows from the assumption that firms have pricing power, so that they can adjust prices in case of a mismatch between supply and demand. I also provide suggestive evidence on the key implications of the model in Appendix A.2.

3 A Dynamic Model of Industry Equilibrium

In this section, I relax the restrictions imposed in the three-period model and analyze firms' cash and inventory decisions (Riddick and Whited (2009) and Bils and Kahn (2000)) in an industry equilibrium which preserves the main qualitative implications derived above. I then estimate the model and explore main implications in a quantitative manner.

Time is discrete and infinite. Within the economy, there is a continuum of firms (of mass one) that operate in a monopolistically competitive market and specialize in the production of differentiated goods, indexed by i. Firms face a downward-sloping demand curve and are subject to financial frictions and idiosyncratic productivity shocks. Each period, after shocks are realized, firms set product prices, produce goods and make financial and dividend payout decisions.

In the subsections below, I first specify the demand curve that each firm faces, their production technology and financing options, and then describe firms' problem and industry equilibrium.

3.1 Demand and Technology

A monopolistically competitive firm i faces a demand function taking the following form,

$$y_i^d = (\frac{p_i}{P})^{-\theta} Q, \tag{8}$$

where $P = [\int_0^1 p_i^{1-\theta} di]^{\frac{1}{1-\theta}}$ and $Q = [\int_0^1 q_i^{\frac{\theta-1}{\theta}} di]^{\frac{\theta}{\theta-1}}$. Here θ denotes the elasticity of substitution between goods, p_i denotes the price charged by firm i, P and Q are industry price and quantity level, and y_i^d is the quantity demanded for good i. This demand curve can be derived from the optimal choices of households. They consume a composite consumption good which is a Dixit-Stiglitz index of differentiated goods in the industry.

Firms face uncertainty from productivity and draw it from the same distribution. Firm i's output is given by

$$y_i = e^{z_i}, \tag{9}$$

where productivity shock z follows an $AR(1)$ process with persistency ρ and innovation ε. The innovation ε has a normal distribution with mean 0 and variance σ^2, $\varepsilon \sim N(0, \sigma^2)$. The idiosyncratic productivity shock z can also be interpreted as firm-specific cost shock: heterogeneity along supply chain may lead to differences in productivity across firms.

3.2 Inventory

Product is storable and let s_i denote the stock of inventory at the beginning of each period for firm i. The sales of the firm, q_i, are constrained to not exceed goods available for sale, that is, goods produced at current period plus inventory transferred from previous period,

$$q_i = \min\{e^{z_i} + s_i, (\frac{p_i}{P})^{-\theta} Q\}. \tag{10}$$

Unsold products are held as inventory and depreciate. The end of period inventory holdings s_i' are therefore given by:

$$s_i' = (1-\delta)(e^{z_i} + s_i - q_i), \tag{11}$$

where δ is inventory depreciation rate, a reduced form parameter capturing various inventory carrying costs that make inventory undesirable and are common to all firms in the industry.

3.3 Financing

Firms need to pay fixed operating costs in advance of production. They can get financing through four different sources: cash flow generated by selling inventory, internal cash balance, intra-period debt, and equity issuance.

Inventory can be sold at the price that firms set at the beginning of each period. The generated cash flow then can be used to fund their operation. Cash balance, c, earns a zero rate of return. The cost of holding cash therefore is the risk-free interest rate.

In addition to internal financing, firms can borrow externally. They can raise funds with an intra-period debt b, but are subject to a borrowing constraint, $b \leq \kappa$. They repay a risk-free interest rate r on their borrowing at the end of each period. Firms can also opt to issue equity. Following Hennessy and Whited (2007), I denote $d \leq 0$ as equity issuance and $d > 0$ as dividend payment. The equity issuance cost is proportional to the amount issued at a rate of λ. I assume that equity financing is more expensive than debt financing, $\lambda > r$. Therefore, debt is preferred to equity as the pecking order theory suggests.

3.4 Firm's Problem

3.4.1 Timing

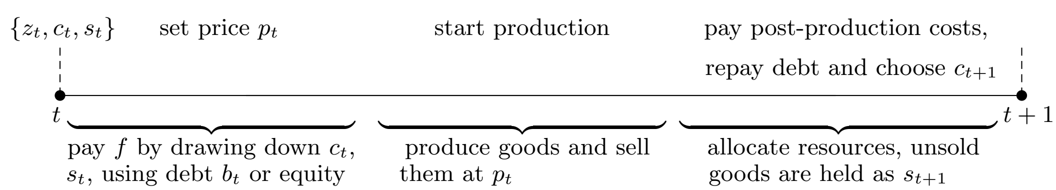
The timeline of the model is illustrated below. At the beginning of period t, after observing the shock z_t, the firm sets a price p_t on its product and needs to pay fixed operating costs f in advance of production. The firm can sell its inventory holdings but is subject to a demand constraint, $q_{1,t} = \min\{s_t, (\frac{p_t}{P_t})^{-\frac{1}{\theta}} Q_t\}$, draw down its cash reserves c_t and raise an intra-period debt under a borrowing constraint, $b_t \leq \kappa$. If these internal and external funds are still insufficient to cover the fixed operating costs, the firm issues equity and pays issuance costs. Otherwise, the unused funds will be used to pay post-production expenses. The net cash flow before production therefore is given by:

$$g(d_{1,t}) = \phi_{d_{1,t}}(1 + \phi_{d_{1,t}}\lambda)d_{1,t},$$

where

$$d_{1,t} = p_t q_{1,t} + c_t + b_t - f.$$

The indicator function $\phi_{d_{1,t}}$ equals one if the firm issues equity before production, and zero otherwise.



After paying the fixed operating costs, the firm starts producing and sells its goods at price p_t which is set at the beginning of the period, but again is subject to a demand constraint, $q_{2,t} = \min\{e^{z_t}, (\frac{p_t}{P_t})^{-\frac{1}{\theta}} Q_t - q_{1,t}\}$. Unsold goods are held as inventory s_{t+1} and transferred to period $t+1$.

In addition to the fixed operating costs, the firm needs to pay post-production costs associated with marketing and advertising. Those costs are proportional to current-period total sales, $\gamma p_t(q_{1,t} + q_{2,t})$. Besides, the firm needs to repay debt and make decisions on cash savings. If resources available are insufficient to cover post-production costs, pay off debt and meet cash saving demand, the firm again issues equity; otherwise, it distributes dividends. The post-production net cash flow is

$$g(d_{2,t}) = (1 + \phi_{d_{2,t}}\lambda)d_{2,t},$$

where

$$d_{2,t} = p_t q_{2,t} + (1 - \phi_{d_{1,t}})d_{1,t} - \gamma p_t(q_{1,t} + q_{2,t}) - (1 + r)b_t - c_{t+1}.$$

The indicator function $\phi_{d_{2,t}}$ equals one if the firm issues equity after production, and zero otherwise. Note that the second term in the expression of $d_{2,t}$ is the funds left after paying fixed operating costs prior to production.

3.4.2 Set-up

The risk neutral firm maximizes the equity value of the firm by choosing product price p_t, intra-period debt b_t and cash holdings c_{t+1}:

$$\max_{p_t, b_t, c_{t+1}} \mathbb{E}\sum_{t=0}^{\infty} \beta^t\{g(d_{1,t}) + g(d_{2,t})\},$$

subject to

$$c_{t+1} \geq 0$$

$$b_t \leq \kappa$$

$$s_{t+1} = (1 - \delta)(e^{z_t} + s_t - q_{1,t} - q_{2,t}) \geq 0,$$

at all dates $t \geq 0$, where the discount factor β equals $\frac{1}{1+r}$.

The problem can be summarized by a Bellman equation. Let $V(z, c, s)$ denote the firm's value as a function of productivity shock, cash stock and inventory holdings. Then the firm's problem is

$$V(z, c, s) = \max_{p,b,c'}\{g(e_1) + g(e_2) + \beta\mathbb{E}V(z', c', s')\}$$

subject to constraints, $b \leq \kappa$, $c' \geq 0$ and $s' \geq 0$. Here prime denotes a variable in the subsequent period.

3.5 Industry Equilibrium

The focus of this paper is a stationary industry equilibrium.

Definition 1 *A* **stationary industry equilibrium** *is a stationary distribution μ, a price P, a quantity Q and policy functions $p(z, c, s; P, Q)$, $b(z, c, s; P, Q)$, and $c'(z, c, s; P, Q)$ such that:*
(i) Policy functions solve the firm's problem given industry price P and quantity Q;
(ii) The distribution μ is invariant over time;
(iii) The product market clears.

4 Quantitative Results

To examine the quantitative implications of the model presented above, I take the model to the data and estimate model parameters with a particular interest in the elasticity of substitution θ.

4.1 Parameterization

The time period t in the model corresponds to one year, that is, firms set product prices once a year. Accordingly, I set the risk-free interest rate r to be 4%, implying the discount factor β to be 0.96.

To calibrate the idiosyncratic productivity shock processes governed by the persistence ρ and volatility σ, I construct a sample of manufacturing firms (SIC 2000-4000) covering the period from 1950 to 2009 from Compustat and use it to estimate the following regression model:

$$\log Y_{i,t} = \alpha_0 + \sum_i firm_i + \sum_t year_t + \epsilon_{i,t}, \tag{12}$$

where $Y_{i,t}$ denotes the real sales of firm i in year t, and the error term $\epsilon_{i,t}$ is the empirical counterpart of the productivity shock $z_{i,t}$ in the model. Firm fixed effects and time fixed effects are also included to control for firm specific time-invariant characteristics and common macroeconomic shocks across firms, respectively. I then collect the estimated residuals from regression model (12) to calibrate ρ and σ. The persistence ρ is obtained directly by estimating the following regression

$$\hat{\epsilon}_{i,t} = \rho\hat{\epsilon}_{i,t-1} + \varepsilon_{i,t},$$

which gives $\rho = 0.73$. I then compute the standard deviation/dispersion of the estimated residuals $\hat{\varepsilon}_{i,t}$ for each year and average it across time. This calculated average gives the volatility of the idiosyncratic productivity shock, $\sigma = 0.38$.

I calibrate the linear post-production costs γ to match the median selling, general and administrative expense (SG&A) to sales ratio. Considering the fact that the expense measure includes salaries of non-sales personnel, I set γ to be 0.2, 75% of the median expense-to-sales ratio.

Table 1: **Model Parameterizations**

Table 1 summarizes the parameters used to solve the model at annual frequency. Panel A reports the parameters calibrated separately by one-to-one matching. Panel B presents the estimation results by taking parameters in Panel A as given and matching nine selected data moments jointly. Standard errors are reported in parenthesis.

Panel A: Parameters Calibrated Separately	
risk-free rate (r)	0.04
persistency of idiosyncratic shock (ρ)	0.73
standard deviation of idiosyncratic shock (σ)	0.38
linear post-production cost (γ)	0.20
Panel B: Parameters Estimated by SMM	
elasticity of substitution (θ)	4.289 (0.0910)
linear costs of equity issuance (λ)	0.106 (0.0034)
inventory depreciation rate (δ)	0.027 (0.0006)
borrowing limit (κ)	0.197 (0.0039)
fixed operating costs (f)	0.298 (0.0133)

Table 1 presents the parameters used to solve the model. Panel A summarizes the parameters discussed above, which are directly calibrated from data. The remaining parameters, reported in Panel B, are estimated by matching moments and discussed in subsection 4.3.

4.2 Comparative Statics

In this subsection, I investigate how firms' cash, inventory and debt decisions respond to changes in several key parameters that are not predetermined: the elasticity of substitution θ, linear equity issuance costs λ, inventory depreciation rate δ and borrowing limit κ. These parameters take the values of equally spaced points in the following intervals respectively: $\theta \in [2, 12]$, $\lambda \in [0.05, 0.20]$, $\kappa \in [0.01, 0.20]$, and $\delta \in [0, 0.10]$. I change one parameter at a time, holding all other parameters at the values close to those in Table 1.

Figure 2 plots the comparative statics results. The panels on the left column show the sensitivity of industry mean of three variables of interest (cash-to-sales, inventory-to-sales and debt-to-sales ratios) with respect to each parameter, while the panels on the right present the sensitivity of industry median of each variable.

The effect of market competition θ, shown in the top two panels, echoes the comparative statics analysis in subsection 2.4. As industry market competition intensifies, industry average cash-to-sales ratio rises, while inventory-to-sales ratio drops. Besides, the debt-to-sales ratio slightly and gradually increases with market competition. This result follows from the drop in firms' total

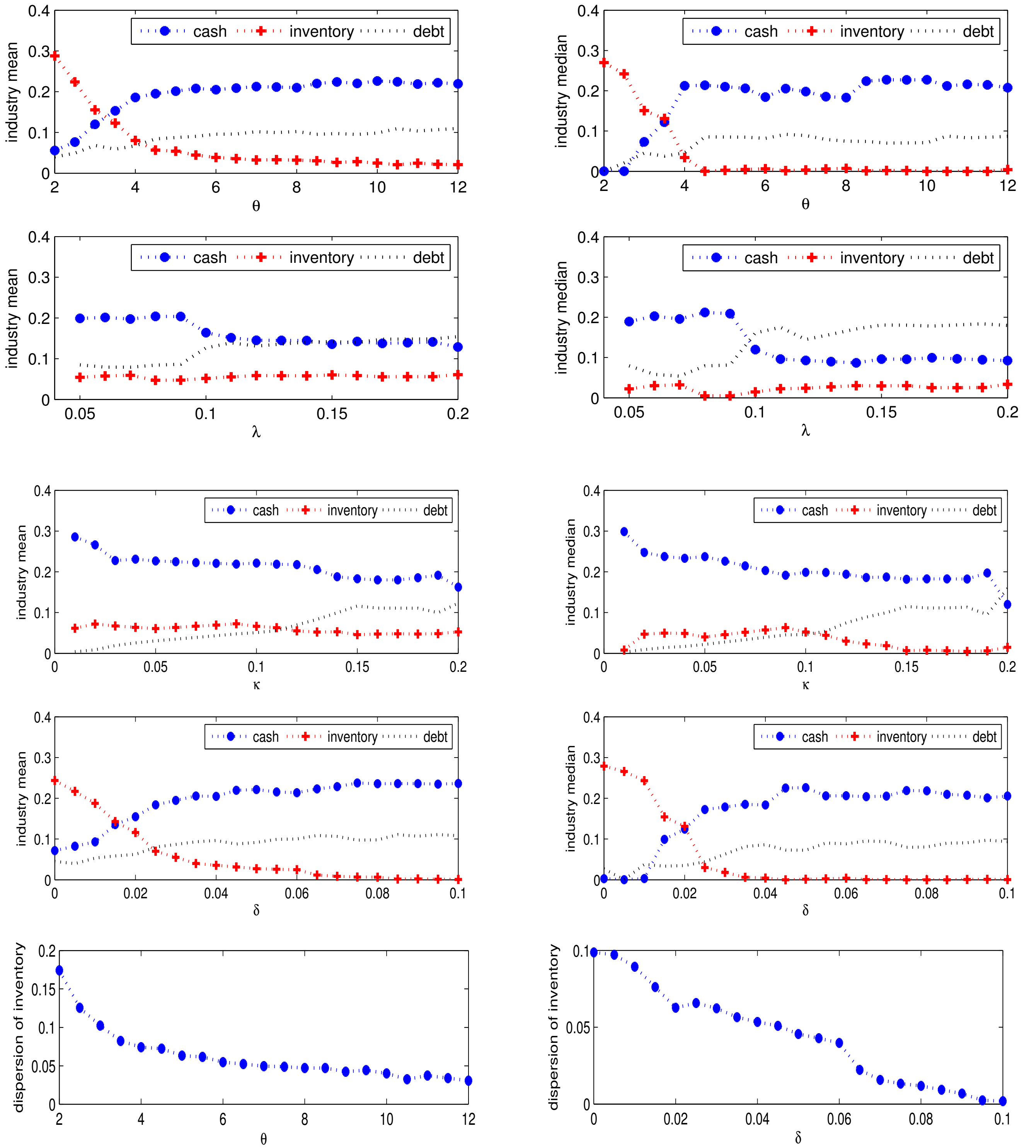


Figure 2: **Comparative Statics of the Dynamic Industry Equilibrium Model.** This figure plots the effects of the elasticity of substitution (θ), linear equity issuance cost (λ), borrowing limit (κ) and inventory depreciation rate (δ) on (i) cash-to-sales ratio, (ii) inventory-to-sales ratio, (iii) debt-to-sales ratio, and (iv) cross-firm dispersion of invenotory-to-sales ratio.

internal resources. In order to fund operating expenses, firms take on more debt. The industry median exhibits very similar patterns but at different levels.

The second row presents the responses of variables to the linear equity issuance cost λ. Overall, cash-to-sales ratio decreases with λ. At first glance, this result seems surprising. It contradicts the implication derived in previous cash models.[4] The possible reason for this difference is that an increase in λ in my model reflects the disadvantage of equity finance relative to debt finance. Therefore, as λ increases, firms rely more heavily on debt finance. The increased usage of debt in turn makes cash less valuable in liquidity management. The inventory-to-sales ratio does not respond to the changes in λ. Its industry mean and industry median stay around 5% and 3%, respectively.

The next two panels show the effects of borrowing limit κ. As κ rises, firms' borrowing constraint is gradually relaxed. This leads to an increased use in risk-free debt and simultaneous reductions in cash and inventory in both industry mean and median.

The sensitivity of variables with respect to inventory depreciation rate δ is depicted in the fourth row. Evidently, the effects of δ on cash and inventory holdings are pretty similar to those of market competition θ, both qualitatively and quantitatively. This is because the inventory depreciation rate essentially captures all the common factors that affect the value of inventory aside from market competition.

To separately identify these two parameters, θ and δ, I need another model moment, namely, the cross-firm dispersion of inventory-to-sales ratio. Intuitively, an increase in inventory depreciation rate (δ) leads to a systematic and homogeneous cut in inventory investment across all firms, regardless of firms' productivity levels. In contrast, because of productivity heterogeneity, an increase in market competition (θ) results in inventory disinvestment of various magnitudes across firms. As a result, inventory depreciation rate is associated with smaller cross-sectional dispersion of inventory ratio relative to market competition. This is confirmed by the results plotted in the bottom two panels.

4.3 Results

I then estimate undetermined parameters using simulated method of moments. I pay close attention to θ, as the comparative statics results shown above suggest that market competition plays a quantitatively important role in shaping firms' cash and inventory policies.

More specifically, I use firm level data from Compustat manufacturing sector for the period 1950 to 2009 and winsorize all variables of interest at the bottom and top 1% level. I then construct data moments by calculating the mean and median of each variable within manufacturing during each period and then taking the median value across periods. The targeted moments include the industry mean and median of cash-to-sales ratio, inventory-to-sales ratio, debt-to-sales ratio and

[4] See, for instance, Riddick and Whited (2009).

cash-to-inventory ratio, as well as the cross-firm dispersion of inventory-to-sales ratio.[5] Lastly, I use these selected data moments to estimate the market competition parameter θ, linear equity issuance cost λ, inventory depreciation rate δ, borrowing limit κ and fixed operating costs f.

The estimated parameters are reported in Panel B of Table 1. Particular attention is paid to the estimate of θ. This deep structural parameter is central to monetary policy analysis, yet there is a lack of clear consensus on its value. In the literature, its estimates range from below 3 to over 10. Using this model and extracting information contained in firms' cash and inventory choices, I find that the average elasticity of substitution for the U.S. manufacturing sector is 4.289, which falls within the lower end of the estimates suggested by the literature.

The value of linear equity issuance cost λ is in line with the range established in previous studies. Hennessy and Whited (2007) estimate a value close to 0.09. Nikolov and Whited (2014) use a model of agency conflicts and find it approximately within the range [0.13, 0.18]. The estimated inventory depreciation rate δ however is below the value used in Alessandria et al. (2010).

Table 2: **Targeted Model Moments**

Table 2 reports both data moments and model moments selected to match. The data moments are calculated based on a sample of manufacturing firms over the period from 1950 to 2009.

Moments	data	model
average cash to sales (c_t/y_t)	0.169	0.157
average inventory to sales (s_t/y_t)	0.073	0.097
average short-term borrowing to sales (d_t/y_t)	0.088	0.080
average relative use of cash ($c_t/(c_t+s_t)$)	0.540	0.524
median cash to sales (c_t/y_t)	0.063	0.129
median inventory to sales (s_t/y_t)	0.055	0.129
median short-term borrowing to sales (d_t/y_t)	0.024	0.031
median relative use of cash ($c_t/(c_t+s_t)$)	0.550	0.500
dispersion of inventory to sales (s_t/y_t)	0.074	0.069

Table 2 presents the nine targeted moments. Overall, the data are well matched. The model generated moments are close to the data moments in most cases, except for industry median cash-to-sales ratio and industry median inventory-to-sales ratio. The latter two model moments overshoot their empirical counterparts, 12.9% versus 6.3% and 12.9% versus 5.5%, respectively.

To further evaluate model performance and validate the model, I examine a number of non-targeted moments, including the overall distributions of cash-to-sales ratio, inventory-to-sales ratio, debt-to-sales ratio and cash-to-inventory ratio. The results are reported in Table 3.

Evidently, the model-implied distributions resemble the data quite well. The exceptions are the 10th and 25th percentiles of cash-to-inventory ratio. Compared with data, the model implies

[5] The theoretical setup focuses on output inventory. Accordingly, here I use finished-good inventory to construct inventory-related moments.

Table 3: **Non-Targeted Model Moments**

Table 3 presents non-targeted moments for cash-to-sales ratio, inventory-to-sales ratio, short-term debt-to-sales ratio and cash-to-inventory ratio. The data moments are calculated based on a sample of manufacturing firms over the period from 1950 to 2009.

Moments	data	model
(i) distribution of cash to sales (c_t/y_t)		
10-percentile	0.010	0.000
25-percentile	0.022	0.015
75-percentile	0.166	0.202
90-percentile	0.278	0.431
(ii) distribution of inventory to sales (s_t/y_t)		
10-percentile	0.000	0.001
25-percentile	0.022	0.026
75-percentile	0.098	0.150
90-percentile	0.158	0.155
(iii) distribution of short-term debt to sales (d_t/y_t)		
10-percentile	0.00	0.00
25-percentile	0.003	0.009
75-percentile	0.077	0.100
90-percentile	0.171	0.197
(iv) distribution of cash to inventory ($c_t/(c_t + s_t)$)		
10-percentile	0.074	0.00
25-percentile	0.207	0.065
75-percentile	0.874	0.881
90-percentile	1.00	1.00

a thinner left tail. The reason for this result is that this model generates a slightly thinner left tail and a slightly fatter left tail of the cash-to-sales and inventory-to-sales distributions. These two minor discrepancies exacerbate the problem when I analyze the cash-to-inventory behavior.

On the whole, the model is able to reproduce the key features of the data. This in turn strengthens the reliability and validity of the estimate of the elasticity of substitution θ.

4.4 Long Run Effects of Intensified Market Competition

Relying on the estimated model, I next perform a counterfactual experiment to examine and evaluate the long run effects of intensified market competition.

A natural way to do that is to raise the value of elasticity of substitution θ. I reset its value to be 5 which implies a 5% drop in firms' markup $\frac{\theta}{\theta-1}$, while fixing all other parameter values as in Table 1. Comparing the new stationary equilibrium with the old one provides information on the long run effects of increased market competition. Results are summarized in Table 4. Panel A reports the industry average output, cash-to-sales ratio and inventory-to-sales ratio. Panel B and C show results for firms with sales at top and bottom 25th percentile.

Table 4: **Long Run Effects of Intensified Market Competiton**

Table 4 summarizes the long run effects of an increase in the degree of competition intensity on within-firm resource allocations. Panel A reports results for industry averages. Panel B and C present results for firms with top and bottom 25 percent of sales, respectively.

	benchmark $\theta = 4.289$	5% drop in markup $\theta = 5$
Panel A: **Effects on Industry Average**		
output (e^{z_t})	1.276	1.275
cash to sales (c_t/y_t)	0.157	0.168
inventory to sales (s_t/y_t)	0.097	0.064
Panel B: **Effects on Top** 25% **(sales) Firms**		
output (e^{z_t})	2.655	2.654
cash to sales (c_t/y_t)	0.002	0.003
inventory to sales (s_t/y_t)	0.171	0.150
Panel C: **Effects on Bottom** 25% **(sales) Firms**		
output (e^{z_t})	0.440	0.439
cash to sales (c_t/y_t)	0.367	0.385
inventory to sales (s_t/y_t)	0.022	0.007

Following a 5% decline in markup, the industry average cash ratio increases from 15.7% to 16.8%, while the industry average inventory ratio declines from 9.7% to 6.4%. These changes are not driven by changes in firm composition in the new industry equilibrium, as the distribution of output barely varies. Instead, they are entirely generated from within-firm resource reallocation. In response to an increase in competitive pressure, all firms in the industry actively adjust their asset portfolios by reallocating resources from inventory to cash.

Table 4 also reveals substantial firm heterogeneity in asset allocations. Panel B and Panel C suggest that firms enjoying higher market shares hold more inventory and less cash, compared to firms with lower market shares. Intuitively, firms with high market shares are firms experiencing high productivity shocks. An expectation of productivity decline creates an expectation of an increase in inventory value and prompts firms to transfer inventory from current period to subsequent period. Having inventory on hand lowers the value of cash holdings and leads firms to save less. These intra-industry implications are consistent with the empirical facts documented in previous studies (see Amihud and Medenelson (1989) and Schoubben and Van Hulle (2012), among others).

4.5 Importance of Joint Analysis of Cash and Inventory

To understand the loss of insight due to analyzing cash and inventory management in isolation, I study two cases in each of which only one of them is considered. I keep all parameters the same as their values in Table 1 and solve firms' problem by alternately excluding one of those two assets out of firms' choice set. I report the corresponding model moments for each case in Table 5.

Table 5: **Importance of Joint Analysis of Cash and Inventory**

Table 5 presents results for two counterfacual models in which only one of the two assets, cash and inventory, is studied. Panel A reports the results of the model without inventory holdings and Panel B shows the results for the model without cash holdings.

Panel A: **Model without Inventory Holdings**	data	model
average cash to sales (c_t/y_t)	0.169	0.217
average inventory to sales (s_t/y_t)	0.073	0.000
average short-term borrowing to sales (d_t/y_t)	0.088	0.123
average relative use of cash ($c_t/(c_t+s_t)$)	0.540	1.000
median cash to sales (c_t/y_t)	0.063	0.189
median inventory to sales (s_t/y_t)	0.055	0.000
median short-term borrowing to sales (d_t/y_t)	0.024	0.108
median relative use of cash ($c_t/(c_t+s_t)$)	0.550	1.000
dispersion of inventory to sales (s_t/y_t)	0.074	0.000
Panel B: **Model without Cash Holdings**	data	model
average cash to sales (c_t/y_t)	0.169	0.000
average inventory to sales (s_t/y_t)	0.073	0.175
average short-term borrowing to sales (d_t/y_t)	0.088	0.126
average relative use of cash ($c_t/(c_t+s_t)$)	0.540	0.000
median cash to sales (c_t/y_t)	0.063	0.000
median inventory to sales (s_t/y_t)	0.055	0.173
median short-term borrowing to sales (d_t/y_t)	0.024	0.102
median relative use of cash ($c_t/(c_t+s_t)$)	0.550	0.000
dispersion of inventory to sales (s_t/y_t)	0.074	0.034

As shown in Panel A, the model without inventory holdings overpredicts the industry average cash-to-sales ratio, 21.7% versus 16.9%. Without the option of carrying inventory from good state to bad state, firms have to accumulate internal resources by saving cash. This result suggests that focusing on the interaction between market competition and cash policy alone tends to underestimate the degree of market competition. That is, the model requires a smaller θ to match data. Similarly, in the model without cash holdings, the simulated inventory-to-sales ratio is twice as large as the empirical counterpart, 17.5% versus 7.3%. Ignoring cash policy while studying inventory management therefore tends to overestimate the degree of market competition.

These findings reinforce the importance of examining cash and inventory management within a unified framework. Isolating cash and inventory from one another and overlooking their interaction shut down one important channel through which market competition affects each choice.

4.6 Robustness

In the baseline model, I assume that inventory can be sold before production to fund operating costs. However, inventory is not so liquid and requires time and effort to convert into cash. In this subsection, I consider a robustness test on this model assumption.

Motivated by the fact that inventory can be pledged as collateral for loans, I modify the baseline model assumption as follows: besides short-term debt financing, firms can also borrow funds by using inventory as collateral at an advance rate of 70% before production; they then sell inventory together with newly-produced goods and repay the loan at the end of the period. To examine how this modification affects the main results, I re-estimate all the parameters reported in Panel B of Table 1 and summarize new results in Table 6.

Table 6: **Robustness Test on Inventory Assumption**

Table 6 summarizes the estimation results under a modified assumption on inventory holdings. Panel A presents the estimated parameters and Panel B reports the nine moments selected to match. Standard errors are reported in parenthesis.

Panel A: Parameters Estimated by SMM		
elasticity of demand (θ)		4.384(0.0606)
linear costs of equity issuance (λ)		0.105(0.0005)
inventory depreciation rate (δ)		0.009(0.0001)
borrowing limit (κ)		0.164(0.0002)
fixed operating costs (f)		0.213(0.0006)
Panel B: Targeted Model Moments	data	model
average cash to sales (c_t/y_t)	0.169	0.115
average inventory to sales (s_t/y_t)	0.073	0.099
average short-term borrowing to sales (d_t/y_t)	0.088	0.069
average relative use of cash ($c_t/(c_t+s_t)$)	0.540	0.569
median cash to sales (c_t/y_t)	0.063	0.095
median inventory to sales (s_t/y_t)	0.055	0.085
median short-term borrowing to sales (d_t/y_t)	0.024	0.054
median relative use of cash ($c_t/(c_t+s_t)$)	0.550	0.591
dispersion of inventory to sales (s_t/y_t)	0.074	0.109

From Panel A, we can see that the effect of the new assumption is mainly absorbed by the estimate of inventory depreciation rate δ. Modelling illiquidity of inventory explicitly is equivalent to isolating one undesirable feature of inventory from others and therefore reduces the value of δ. The depreciation equivalent of the new assumption is 1.8 percentage points. The estimate of the elasticity θ however is robust to this modification. Its value changes slightly from 4.289 to 4.384.

Moreover, as suggested by Panel B, the modified model also matches most moments reasonably well.

5 Conclusion

While previous studies analyze cash and inventory management in isolation, I in this paper consider them jointly, given the close linkage between these two margins in working capital management. More specifically, I examine the tradeoff firms face when they allocate limited resources between cash and inventory.

To understand this tradeoff and illustrate the main ideas, I start by developing a simple three-period model that assumes uncertain productivity shocks and imperfect capital markets. In the model, the degree of market competition largely affects firms profitability as well as the return on holding inventory. Firms facing relatively inelastic demand have greater pricing power. They are able to set a higher price over cost and to transfer more goods across time without lowering future prices significantly. Those firms therefore find themselves more likely to benefit from carrying inventory. The presence of inventory stock not only locks up internal resources but also reduces the value of holding cash, thus leads to a lower cash balance.

I then extend the three-period model to a dynamic industry equilibrium and examine the tradeoff quantitatively. I first show comparative statics results, which confirm the quantitative importance of market competition in determining the tradeoff between cash and inventory. I then exploit this model implication to infer the degree of market competition for the manufacturing sector from its cash and inventory choices. The estimated model behaves consistently with data. Lastly, using the model as a laboratory, I conduct an experiment to evaluate the effect of an intensified market competition. I find that a 5% drop in markup prompts firms to cut inventory holdings by 3.3% and raise cash balance by 1.1%.

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A Appendix

A.1 Variable Definitions

I define variables used in the cash-to-cash and inventory regression as follows:
Cash-to-cash and inventory is defined as the ratio of cash over the sum of cash and inventory holdings, where cash is measured as cash, cash equivalents and short-term investments;
Markup is measured as sales over the sum of cost of goods sold and selling, general and administrative expenses;
Risk dispersion is the standard deviation of idiosyncratic productivity shock within one industry;
Firm size is the natural logarithm of total assets;
Risk is computed as the standard deviation of annual operating cash flow in the past five years, with operating cash flow defined as earnings after interest, dividends and tax but before depreciation divided by total assets;
Market-to-book ratio is the sum of market value and debt over total assets;
Net working capital is equal to working capital net of cash and inventory over total assets;
Capital investment is the ratio of capital expenditure over total assets;
Leverage is the sum of long-term debt and debt in current liabilities normalized by total assets;
R&D investment is research and development expenses to total asset ratio;
Dividend is a dummy variable taking value of one if dividend payout (common) is non-zero;
Acquisition is the ratio of acquisition over total assets.

A.2 Suggestive Evidence

In this section, I provide suggestive evidence to support the central insight of the model. I exploit within-industry over-time variation to identify the effect of market competition on firms' cash and inventory management.

The regression model is specified as follows:

$$\begin{aligned}\frac{cash}{inventory + cash}_{i,t} &= \alpha_0 + \alpha_1 markup_{i,t} + \alpha_2 risk\ dispersion_{i,t} + \alpha_3 firm\ size_{i,t} \\ &+ \alpha_4 market\ to\ book_{i,t} + \alpha_5 cash\ flow_{i,t} + \alpha_6' X_{i,t} + \sum_i industry_i \\ &+ \sum_t year_t + \epsilon_{i,t}, \qquad \text{(A.1)}\end{aligned}$$

where i refers to industry and t is time. For each industry i and period t, I calculate variables at firm level and then take average across firms. All variables are measured as their industry mean during period t, except for intra-industry risk dispersion whose measurement will be explained below.

In this regression, dependent variable is the ratio of cash to the sum of cash and inventory holdings. This ratio reflects the relative holdings of cash versus inventory in firms' assets, as suggested in Sufi (2009) and Acharya et al. (2013). Industry-level market competition is proxied by industry average markup, reflecting firms' ability to set prices over costs. It is measured by sales over the sum of cost of goods sold (COGS) and selling, general and administrative expense (XSGA). To measure the intra-industry risk dispersion, I first obtain the productivity shocks of each firm within industry i during period t by regressing the sales of each firm in that industry during that period on their capital stock and labor, and then compute the standard deviation of those shocks.

Other covariates include firm size, within-firm risk, market-to-book ratio, capital investment, net working capital, leverage, R&D expenditures, a dividend dummy, and acquisition expenses. These variables are constructed in the same way as those used in other empirical cash studies. I include industry dummy variables to remove industry specific effects and include year dummy variables to capture the common trend across industries.

Table A1: **Summary Statistics: Industry Level**

Table A1 presents descriptive statistics for the industry mean of each variable used in the regression equation (A.1). It reports the mean, median, standard deviation, 25th and 75th percentile, and number of observations. The sample is constructed from Compustat Annual files from 1970 to 2009. A detailed definition of variables is provided in Appendix A.1.

Variables	Mean	Median	Std. Dev.	25%	75%	Obs.
Cash-to-(Cash+Inventory)	0.34	0.31	0.15	0.22	0.41	3482
Markup	1.06	1.08	0.11	1.02	1.12	3482
Tariff	0.04	0.04	0.02	0.02	0.05	1536
Risk dispersion	0.49	0.41	0.28	0.28	0.61	3482
Size	4.14	3.97	1.36	3.17	4.93	3482
Within-firm risk	0.07	0.04	0.07	0.03	0.09	3480
Market-to-Book	1.73	1.34	1.19	0.92	2.14	3482
Cash flow	-0.05	0.02	0.18	-0.10	0.06	3482
Net working capital	0.01	0.06	0.23	-0.04	0.14	3478
Capital investment	0.06	0.06	0.02	0.04	0.07	3482
Leverage	0.27	0.27	0.08	0.22	0.32	3482
R&D	0.07	0.04	0.08	0.02	0.09	3450
Dividend dummy	0.40	0.39	0.24	0.20	0.58	3482
Acquisition	0.02	0.01	0.02	0.00	0.02	3428

Variables are constructed from Compustat Fundamentals Annual files and winsorized following Bates et al. (2009). I focus on manufacturing firms and eliminate all industries with fewer than five firms in Compustat. Table A1 shows summary statistics for the regressor variables at the industry level during the period from 1970 to 2009. I first calculate the mean of each variable (except for intra-industry risk dispersion) for each industry during each period and then take average across periods. The mean and median of industry cash-to-cash and inventory ratios are 29% and 26% respectively. Explanatory variables have similar characteristics to those in previous studies.

Table A2: **The Choice between Cash and Inventory**

Table A2 reports the results of regression model (A.1) on markup, risk dispersion, size, risk and other commonly-included control variables. Industry and year fixed effects are included in the regressions and the heteroskedasticity-consistent standard errors reported in parenthesis. Significance levels are indicated by *, **, and *** for 10%, 5%, and 1%, respectively.

Variables	Cash-to-(Cash+Inventory)			Markup
	OLS	IV		first stage
	(1)	(2)		(3)
Markup	**-0.191*****	**-0.838****	Tariff	0.714***
	(0.037)	(0.351)		(0.173)
Risk dispersion	0.037**	0.047***		-0.003
	(0.009)	(0.013)		(0.011)
Size	0.014***	0.041***		0.02**
	(0.005)	(0.01)		(0.007)
Within-firm risk	0.007	0.045		-0.128**
	(0.038)	(0.15)		(0.052)
Market-to-Book	0.015***	0.023***		0.006*
	(0.003)	(0.004)		(0.003)
Cash flow	0.017	0.23*		0.35***
	(0.027)	(0.128)		(0.027)
Net working capital	-0.066***	-0.088***		-0.053***
	(0.011)	(0.025)		(0.010)
Capital investment	-0.111	-0.059		0.167
	(0.119)	(0.185)		(0.143)
Leverage	-0.500***	-0.462***		0.072
	(0.035)	(0.077)		(0.05)
R&D	0.06**	0.055		-0.019
	(0.03)	(0.038)		(0.036)
Dividend	-0.011	0.006		0.069***
	(0.021)	(0.048)		(0.025)
Acquisition	0.045	-0.072		0.16
	(0.097)	(0.215)		(0.281)
Industry FE (4-digit)	Yes	Yes		Yes
Year FE	Yes	Yes		Yes
Observations	1865	860		860
R-squared	0.89	0.85		0.83
			F-test	19.66

Table A2 presents the estimation results of regression model (A.1). The variable of particular interest is industry-level markup. In accordance with model predictions, the result in Column (1) suggests that the cash-to-cash and inventory ratio declines with markup. A 1% decrease in markup is associated with an approximate 0.2% increase in industry average cash-to-inventory ratio. Since the causality can go either way, I next use an instrumental variables approach to address the concerns about the potential endogeneity. Following Fresard (2010), I instrument industry average markup with changes in industry-level import tariffs.[6] The coefficient on markup remains negative and statistically significant.

[6] The 1989-2005 US tariff data are available from Peter Schott's website.