

Precautionary Pricing

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Abstract

Firms set prices and production quantities before demand is realized, exposing them to the risk of excess inventories or stock-outs. I develop a model in which risk-averse firms choose prices and inventories under idiosyncratic demand uncertainty. Precautionary behavior generates dispersion in prices and markups even with constant demand elasticity, as firms trade off insuring against surpluses versus rationing. Quantitatively, the model replicates observed relationships between volatility, inventory investment, and markup dispersion in U.S. data. During supply-chain disruptions, heightened stock-out risk raises aggregate markups and delays recovery, revealing how firm-level risk aversion amplifies aggregate fluctuations.

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1 Introduction

In most industries, firms must determine production quantities and prices prior to the realization of demand. Such timing exposes them to idiosyncratic uncertainty: unexpected surpluses of inventories when demand is weak or costly stock-outs when demand is strong. These risks are particularly salient for firms introducing new or seasonal products, where pricing and production decisions are taken in advance of sales. Despite the ubiquity of this environment, the role of idiosyncratic risk and risk aversion in firms' price-setting behavior remains largely unexplored in the literature.

This paper develops a model of precautionary pricing in which risk-averse firms choose prices and inventories before demand is realized. Firms face idiosyncratic, persistent shocks to demand and cannot insure against the resulting fluctuations in revenues. As a consequence, they behave as if they were insuring against future shortages or surpluses. This precautionary motive generates dispersion in prices and markups, even though the elasticity of substitution across goods is constant. Firms with weaker balance sheets or greater exposure to demand volatility set higher markups to mitigate the risk of stock-outs, whereas financially unconstrained firms adopt lower prices and higher inventory levels.

The model introduces a trade-off between insuring against the risk of unsold inventories and insuring against the risk of stock-outs. Firms that emphasize insurance against rationing of demand choose higher markups and lower inventories. Aggregating across firms, these heterogeneous responses give rise to variation in markups and utilization rates, leading to misallocation and losses in aggregate productivity. I further show that during a supply-chain disruption, which raises the idiosyncratic risk of stock-outs, aggregate markups increase and recovery is delayed relative to an economy with risk-neutral firms. Thus, firm-level risk aversion and incomplete insurance can amplify and prolong supply-side crises.

Quantitatively, the model is calibrated at an annual frequency to match moments on the volatility of sales and inventories from Compustat, the prevalence of stock-outs documented in the literature, and the observed inequality in entrepreneurial wealth. The model reproduces the dispersion of markups and inventory behavior observed in the data. In the empirical analysis, using a panel of U.S. nonfinancial corporations from 2001 to 2019, I show that firms facing greater idiosyncratic volatility in stock returns invest less in inventories, and that this effect is amplified when executives hold equity stakes in their firms. Moreover, variation in firm-specific volatility and managerial exposure accounts for 10 to 25 percent of observed markup dispersion.

1.1 Related Literature

This paper contributes to three strands of literature. First, it contributes to the literature on inventory dynamics and their implications for macroeconomics. Papers such as [Bils and Kahn \(2000\)](#), [Khan and Thomas \(2007\)](#), and [Wen \(2011\)](#) study the role of inventories for amplification of macro shocks. Relative to this literature, I introduce a mechanism through which idiosyncratic risk and risk aversion jointly shape price-setting and inventory policies. In addition, I follow [Alessandria et al. \(2023\)](#) in studying supply chain crises, modeling the crisis as an increase in the probability of shipment delays.

Distinct from but related to the inventories literature is [Flynn et al. \(2025\)](#). They focus on firms committing to a production schedule given realizations of demand. While dynamic pricing is not uncommon, in both goods market pricing and output decisions are commonly predetermined. In the goods market there is a great deal of price rigidity concurrent with significant inventory holdings.¹ Hence, I take a starker view that firms are restricted to only a particular price and quantity rather than a locus of prices and quantities.

Second, it contributes to the literature on firm dynamics and markups. Previous work such [Edmond et al. \(2023\)](#), [Baqae et al. \(2021\)](#), and [De Loecker et al. \(2020\)](#) emphasize the role of markup dispersion among firms. Relative to the literature, where size-dependent markups are common, I provide a micro-foundation for markup dispersion arising from incomplete insurance rather than from heterogeneity in demand elasticities, technological differences, or firm-size.

Lastly, it contributes to the literature on firm dynamics and risk. [David et al. \(2022\)](#) provide a framework linking misallocation in capital to risk rather than financial frictions. Similarly, [Boar et al. \(2022\)](#) study a model where misallocation in product markets is due primary to risk. Relative to these two papers, I introduce pricing and inventory choice as separate policies and study the implications of risk as a primary friction. Lastly, [Di Tella et al. \(2025\)](#) study the optimal taxation when markups are due to risk. Relative to their paper, I disentangle the sources of risk that firms are exposed, arising from stock-outs and surpluses, which I find contribute to markup variation.

2 Model

Time is discrete. Economy is populated by a representative worker, a final good producer, and a unit mass of firms. Representative workers supply labor and save/borrow in risk-free

¹Same can also be said for services. For instance, restaurants choose prices for the menus in advance. In this case, inventories are not held in the final good but instead in the raw inputs that are used to produce the services.

bonds. They supply labor to intermediate good firms which use the labor along with capital to produce inventories for differentiated goods. Sales of inventories are combined by a final good producer. Intermediate good firms are not allowed to borrow and must price and order their inventories prior to demand realizing for their product. Their firm specific demand is subject to persistent idiosyncratic shocks. There is no aggregate uncertainty.

2.1 Representative Worker

The representative worker objective is to maximize their lifetime utility. They discount time with $\beta_w \in (0, 1)$ and have period utility $U(C_w, L_w)$ over consumption C_w and labor L_w . Their problem stated recursively is

$$\begin{aligned} V_{w,t}(B_w) &= \max_{L_w, B'_w} U(C_w, L_w) + \beta_w V_{w,t+1}(B'_w) \\ C_w + B'_w &\leq (1 + r_t)B_w + W_t L_w \end{aligned}$$

They face interest rate r_t and wages W_t . They can borrow subject to the natural borrowing limit. I assume period utility is CRRA with separable disutility from labor, that is $U(C, L) = \frac{C^{1-\gamma}}{1-\gamma} - \Psi \frac{L^{1+\eta}}{1+\eta}$, with coefficient of relative risk aversion γ and inverse Frisch elasticity η . Therefore, labor and savings choices are such that the following first order conditions hold

$$\begin{aligned} W_t &= \Psi C_{w,t}^\gamma L_{w,t}^\eta \\ \beta_w \left(\frac{C_{w,t}}{C_{w,t+1}} \right)^\gamma &= \frac{1}{1 + r_{t+1}} \end{aligned}$$

2.2 Final Good Firm

Final good firm combines output y_i for firms $i \in [0, 1]$ to produce Y . They have CES technology such that

$$Y = \left(\int \theta_i^{\frac{1}{\sigma}} y_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}$$

where θ_i is a demand shock for firm i . Intermediate good firms sell their output at prices p_i and supply goods up to their available inventories, I_i . As the final good firm is perfectly competitive, their problem is

$$\min_{y_i} \left\{ \int p_i y_i di \mid Y = \left(\int \theta_i^{\frac{1}{\sigma}} y_i^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, y_i \leq I_i \quad \forall i \right\}$$

Demand for good i is:

$$y_i = Y \left(\frac{p_i + \lambda_i}{P} \right)^{-\sigma} \theta_i$$

where λ_i be the multiplier if firm i experiences a stockout which can be expressed as

$$\lambda_i = \max \left\{ P \left(\frac{I_i}{Y} \right)^{-\frac{1}{\sigma}} \theta_i^{\frac{1}{\sigma}} - p_i, 0 \right\}$$

The aggregate price index P is

$$P^{1-\sigma} = \int \theta_i (p_i + \lambda_i)^{1-\sigma} di$$

The aggregate price index P is not equivalent to the CPI, as in the case of standard CES models. Let $P_{cpi} = \int p_i \frac{y_i}{Y} di$. We can relate aggregate price index and P using

$$P = P_{cpi} + \int \lambda_i \frac{I_i}{Y} di$$

Differences between CPI and price index due to covariance between μ_i and I_i . Aggregate price index is smaller if firms with low levels of inventories are rationing their demand. Going forward, I set the aggregate price index as numéraire, $P = 1$.

2.3 Intermediate Good Firms

Intermediate good firms face restrictions in selling their goods. They must set prices and choose output one period in advance. As a consequence, their choices are subject to demand uncertainty. A firm enters the period with prices p_t , inventories of their good I_t , and savings a_t , all determined at $t - 1$. In the beginning of the period demand θ_t is realized which is uncertain and demand for the firm's good is $y_t = Y_t p_t^{-\sigma} \theta_t$. They can at most earn $p_t \min \{y_t, I_t\}$ in revenue. They can end up with a surplus in inventories or ration demand depending on realizations of θ_t .

In the end of period t , they produce new inventories I_{t+1} by hiring labor ℓ_t at wage W_t and producing using CRS technology. They save in bonds a_{t+1} subject to a no borrowing condition. Lastly, they set tomorrow's price p_{t+1} . A fraction $(1 - \delta_I)$ unsold inventories can

be liquidated. The firm's problem recursively

$$\begin{aligned}
V_t(\theta, m) &= \max_{p', I', a'} u(c) + \beta \mathbb{E}_t [V_{t+1}(\theta', m'(p', I', a'))] \\
c &\leq m - a' - W_t I' \\
m' &= p' \min \{y', I'\} + (1 + r_{t+1})a' + (1 - \delta_I) \min \{I' - \min \{y', I'\}\} \\
y' &= Y_{t+1} (p')^{-\sigma} \theta' \\
0 &\leq a'
\end{aligned}$$

Their period utility is $u(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma}$. Firm demand evolves according to

$$\log \theta' = \rho_\theta \log \theta + \nu'$$

where

$$\nu' \sim \begin{cases} N(0, \sigma_\theta) & \text{with prob. } \chi \\ N(0, \tilde{\sigma}_\theta) & \text{with prob. } (1 - \chi) \end{cases}$$

Demand evolves according to an log autoregressive with innovations that are a mixture of two normals, where $\tilde{\sigma}_\theta > \sigma_\theta$, and are mixed with probability $\chi \in (0, 1)$. This will generate significant risk in pricing since demand will be subject to fat-tailed shocks. The firm's state is their demand and cash-on-hand m , which consists of sales of intermediate good, savings, and liquidated inventories. Let $F(\theta, m)$ be the distribution of intermediate good firms in the space of (θ, m) .

2.4 Discussion

Timing. Firms are restricted to choosing output and prices one period in advance. Time-to-build is natural for capital and inventories. It is well-established at business cycle frequency prices are sticky. In the environment I present, firms introduce new prices through new products. One should view these as single product firms, which introduce a new price and product. This is natural in consumer goods such as electronics and clothing. Certain goods are “in-season” for period of time and then new iterations introduced with new prices. [Argente et al. \(2024\)](#) show that prices fall for products over their lifetime and new products are introduced with newer, higher prices.

Liquidation. I allow the firm to claim a fraction of unsold inventories for consumption. Compared to other models (i.e. [Kryvtsov and Midrigan \(2013\)](#)) I am allowing reversibility in inventories. Crucial difference in this setting is the frequency. I consider a model with

lower frequency. I calibrate the model to an annual frequency. At business cycle frequency, it is natural to think that inventories are irreversible. However, at annual frequency this assumption is unlikely to be accurate. Markets for liquidation and fire sale of unsold inventories are well established.² I abstract from characterizing this market and assume firms take a significant hair-cut on their unsold inventories.

Risk Aversion. I assume a firm is managed by a single entrepreneur that owns the firm outright. In reality, firms are managed by multiple managers. In case of public firms, these managers share a stake in the firm's earnings alongside other shareholders. I will show in the empirical analysis, public firms exhibit evidence of risk aversion through their inventory investment. As the firms' executives have a higher ownership stake, their inventory investment is attenuated relative to firms with unexposed executives. This result replicates a well known result for capital investment found in [Panousi and Papanikolaou \(2012\)](#). A model with risk-neutral firms will imply prices and inventories are only a function of exogenous variation in demand. Data suggests variation in inventories related strongly to the firm's balance sheet and the exposure of firms' executives to earnings. Both these facts are consistent with risk aversion but not consistent with risk-neutrality.

2.5 Analysis

Policies. The firm's first order condition for savings a'

$$u'(c) = \beta(1 + r_{t+1} + \mu)\mathbb{E}_t(V_{m,t+1})$$

where multiplier on $a' \geq 0$ is μ and $V_{m,t+1} \equiv \frac{\partial V_{m,t+1}(\theta, m)}{\partial m}$. The first order condition for new inventories I' is

$$u'(c)W_t = \beta\mathbb{E}_t[V_{m,t+1}\{\mathcal{X}_{t+1}p' + (1 - \mathcal{X}_{t+1})(1 - \delta_I)W_{t+1}\}]$$

where $\mathcal{X}_t = \mathbb{I}(y' \geq I')$, indicator of stockout. To simplify expressions going forward, define $\hat{\mathbb{E}}_t(X) \equiv \frac{\mathbb{E}[V_{m,t+1}X]}{\mathbb{E}[V_{m,t+1}]}$, which is the expectations operator taken under the risk neutral measure. Combining the two optimality conditions,

$$(1 + r_{t+1} + \mu)W_t = \hat{\mathbb{E}}_t[\mathcal{X}_{t+1}p' + (1 - \mathcal{X}_{t+1})(1 - \delta_I)W_{t+1}]$$

²NAICS sector 561990 includes inventory liquidators.

On the left-hand side $(1 + r_{t+1} + \mu)W_t$ is the marginal cost of inventories. It includes the labor hired, W_t , the opportunity cost of saving instead, r_{t+1} , and cost of financial frictions μ . On the right-hand side is the marginal benefit of inventories. In case of shock outs, i.e. $\mathcal{X}_{t+1} = 1$, one earns p' in revenues. Also, if there is no stockout, then one earns the liquidation value of the inventories.

The first order condition for p' is

$$p' = \frac{\sigma \hat{\mathbb{E}}_t [y'(1 - \mathcal{X}_{t+1})]}{\hat{\mathbb{E}}_t [(\sigma - 1)y'(1 - \mathcal{X}_{t+1}) - I' \mathcal{X}_{t+1}]} W_{t+1}(1 - \delta_I)$$

While this close to an expression of prices as a markup over a marginal cost of production, $W_{t+1}(1 - \delta_I)$ is not the marginal cost but rather the liquidation value. We can arrive at a familiar pricing expression by combining this optimality condition with the one for inventories, such that

$$p' = \underbrace{\frac{\hat{\sigma}}{\hat{\sigma} - 1}}_{\text{markup}} \underbrace{W_t(1 + r_{t+1} + \mu)}_{\text{marginal cost}} \quad (1)$$

where markups are a Lerner index of the “effective” demand elasticity $\hat{\sigma}$. This elasticity can be expressed as

$$\hat{\sigma} = \sigma \frac{\hat{\mathbb{E}}_t (y'|y' \leq I')}{\hat{\mathbb{E}}_t (\min \{y', I'\})} \quad (2)$$

which is the elasticity of substitution σ under CES scaled by the expected output conditional on not stocking-out relative to expected sales, all under the risk-neutral measure. Note that $\hat{\sigma} \leq \sigma$ hence markups are higher due to demand uncertainty.

Very importantly in this environment markups vary with respect to wealth. Why? Note that $\hat{\sigma}$ vary with respect to (θ, m) , the idiosyncratic state of the firm. This is because expectations are conditioned on $V_m(\theta, m)$. By the envelope theorem: $V_m(\theta, m) = u'(c)$, hence expectations are weighted by marginal utility of consumption. The covariance between consumption and outcomes will be relevant for inventory demand and pricing. If output is lower in bad states of the world, i.e. $\hat{\mathbb{E}}_t (y'|y' \leq I') \leq \mathbb{E}_t (y'|y' \leq I')$, then $\hat{\sigma}$ falls, and markups increase. Similarly if probability of a stock-out is correlated with low consumption.

Markups in this environment reflect (1) market power due to monopolistic competition, (2) variable utilization as demand is uncertain, and (3) risk. The risk occurs because shortfalls in demand are correlated with low consumption. Due to this, risk averse firms will choose to price with a markup to be compensated for risk.

Risk Neutrality. To understand the relevance of risk, it is useful to compare to the risk neutral benchmark. Suppose p' and I' are chosen by a firm with risk neutral preferences or in an environment with complete markets. A firm that chooses price p' and inventories I' experiences a stockout if $y' \geq I'$. Substituting in demand y' , stock-outs occur if:

$$Y_{t+1}(p')^{-\sigma} \theta^\rho \exp(\nu') \geq I'$$

Therefore, stock-out occur if $\nu \geq \bar{\nu}$ where

$$\bar{\nu} \equiv \log \left(\frac{I'}{Y_{t+1}(p')^{-\sigma} \theta^\rho} \right)$$

This is the cutoff for the innovation in demand such that any innovations above this level lead to stock-outs. With risk neutrality, the first order conditions of the firm no longer involve the risk neutral measure. Combining the conditions for inventories and prices, the firm's policy then is a cutoff $\bar{\nu}$. This is a similar result to papers on inventory dynamics and business cycle such as [Kim \(2021\)](#) and [Wen \(2011\)](#). The choice of $\bar{\nu}$ is isomorphic to the probability of stock-outs. Implicitly, the risk neutral firm chooses the probability of stock-outs and then backs out the unique pair of p' and I' to generate such outcomes. In addition, note that $\bar{\nu}$ is state-independent. In fact, it is only a function of wages, elasticity of demand σ , and distribution of the innovation ν . Therefore, the ex-ante stockout probability without risk aversion is state-independent. As ex-ante stock-out probabilities are constant across firms, we have the following implication:

Proposition 1. *If a firm is risk neutral then prices, p' , are constant with respect to (θ, m)*

As a corollary markups are constant and do not vary across risk-neutral firms. This is because costs are identical. In their environment, only differences that demand θ generates is differences in sales. As a consequence, in the baseline model, with risk-averse firms, any and all markup or price dispersion is due to differences in risk exposure. Variation in markups will be purely due to risk. Variation in prices will also include a portion due to costs of borrowing passed on to the consumer.

Aggregate Markup. Define the aggregate markup $\mathcal{M}_t$ implicitly as

$$\frac{W_t(1 + r_t)L_{w,t}}{Y_t} = \frac{1}{\mathcal{M}_t}$$

which admits a harmonic average representation:

$$\frac{1}{\mathcal{M}_t} = \int \frac{p_{i,t} \min\{y_{i,t}, I_{i,t}\}}{Y_t} \frac{1}{m_{i,t}} \frac{1}{1 + \mu_{i,t}/(1 + r_t)} \frac{1}{\omega_{i,t}} di$$

where $m_{i,t} = \frac{\hat{\sigma}_{i,t}}{\hat{\sigma}_{i,t}-1}$ is the markup and $\omega_{i,t} = \frac{\min\{y_{i,t}, I_{i,t}\}}{I_{i,t}}$ is the utilization rate of inventories. Markup dispersion will lead to misallocation loss, similar to other models with markup dispersion. In addition, dispersion in utilization rate contributes to misallocation. Finally, financial friction contribute to misallocation. The borrowing wedge $\mu_{i,t}$ is present in the markup expression. Hence, variation in financing costs will impact aggregate markups.

Aggregate Productivity. Define aggregate productivity Z_t implicitly as $Y_t = Z_t I_t$ where I_t is the aggregate stock of inventories. Aggregate productivity can be expressed as

$$\frac{1}{Z_{t+1}} = \frac{\sigma - 1}{\sigma} \int \frac{\hat{\mathbb{E}}_t(\min\{y_{i,t+1}, I_{i,t+1}\})}{Y_{t+1}} \frac{1}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})} \frac{1 - \frac{\sigma}{\sigma-1} \frac{1}{m_{i,t+1}} \frac{1-\delta_I}{1+r_{t+1}+\mu_{i,t+1}}}{1 - \frac{1}{m_{i,t+1}} \frac{1-\delta_I}{1+r_{t+1}+\mu_{i,t+1}}} di$$

Aggregate productivity is also a harmonic average. Within the integral the first term is the expected sales of the firm under the risk neutral measure. The second term is the inverse of the stock-out rate, also under the risk neutral measure. The final term in the integral reflects the differences between markups from the frictionless level under CES, $\frac{\sigma}{\sigma-1}$. To understand the terms above more concretely, I define $s_{i,t} = \frac{\min\{y_{i,t}, I_{i,t}\}}{Y_t}$ as the output share. In addition define

$$\zeta_{i,t} = \frac{1 - \frac{\sigma}{\sigma-1} \frac{1}{m_{i,t+1}} \frac{1-\delta_I}{1+r_{t+1}+\mu_{i,t+1}}}{1 - \frac{1}{m_{i,t+1}} \frac{1-\delta_I}{1+r_{t+1}+\mu_{i,t+1}}}$$

$$\xi_{i,t} = \frac{Cov_{i,t}(u'(c_{i,t+1}) \min\{y_{i,t+1}, I_{i,t+1}\})}{E_{i,t}[u'(c_{i,t+1})] E_{i,t}[\min\{y_{i,t+1}, I_{i,t+1}\}]}$$

Here $\zeta_{i,t}$ is a wedge reflecting the gap between realized markups $m_{i,t}$ and the frictionless counterpart. The wedge $\xi_{i,t}$ is the risk firms are exposed to, the covariance between their marginal utility of consumption and realized sales. If a firm has full insurance, we expect $\xi_{i,t} = 0$, and other wise $\xi_{i,t} < 0$. We can express aggregate productivity as

$$\frac{1}{Z_{t+1}} = \frac{\sigma - 1}{\sigma} \int s_{i,t} (1 + \xi_{i,t}) \frac{\zeta_{i,t+1}}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})} di$$

That is aggregate output is a output-weighted harmonic average of important cross-sectional wedges. To understand the sources of misallocation, I begin with the tractable case where

inventories fully depreciate, $\delta_I = 1$. This means that $\zeta_{i,t} = 1$ for all i . If firms are can fully insure against uncertain demand then using Proposition 1 we know that ex-ante probability of stockout is common across firms. Let Z_t^* be productivity in this counterfactual and let $\mathbb{P}^*$ be the stockout probability common to all firms in that equilibrium. If we hold distribution of $s_{i,t}$ constant, it follows that

$$\log \left(\frac{Z_{t+1}^*}{Z_{t+1}} \right) \approx \mathbb{E} \left(\log \frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})} \right) + \mathbb{E}(\log(1 + \xi_{i,t})) \quad (3)$$

$$+ \frac{1}{2} \left[\mathbb{V}ar \left(\log \frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})} \right) + \mathbb{V}ar(\log(1 + \xi_{i,t})) \right] \quad (4)$$

$$- \mathbb{C}ov \left(\log \frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})}, \log(1 + \xi_{i,t}) \right) \quad (5)$$

Consequence of this result is that risk misallocates through dispersion in ex-ante stockout rates. Equation (3) is a second order expansion of the productivity gap between full insurance and benchmark model. The first term is the average distance between the insured firms' stock-out rate and stock-out rate in the incomplete-markets economy. The second term is the risk-wedge, the average risk wedge increases losses as it implies more output is allocated to exposed firms, whom we expect to price with a significant markup. The third and fourth terms are dispersion in stockout rates and risk wedge. More dispersion in stockout rates or risk wedge leads to greater misallocation loss due to incomplete insurance.

This provides a prediction for the degree of misallocation due to risk as a function two margins: An extensive margin reflecting the stock-out rate and an intensive margin reflecting how much of inventories are sold. For the extensive margin, it is summarized mean and variance of the gap between stock-out rates under complete insurance and stock-out rates faced by risk averse firms under their risk neutral measure. Due to Proposition 1, I can conveniently solve for $\mathbb{P}^*$ without prices as it is a function only of model primitives. The intensive margin is similarly summarized by the first two moments.

Very importantly, the two margins will push misallocation in opposite directions. The extensive margin will increase misallocation. As I will show in the following sections, this margin is associated with significant risk markups. The intensive margin on the other hand will be negative, hence reducing misallocation. Why? The logic is similar to [Ebsim \(2025\)](#), risk markups are allocated to firms with high marginal utility, hence allowing them to mitigate their risk through profits.

2.6 Equilibrium

My analysis will focus on stationary equilibrium. To that end:

Definition 1. *A stationary equilibrium is interest rate r , output Y , wage W such that given r, Y , and W , :* (1) B_w, L_w are optimal for the worker. (2) $p'(\theta, m), I'(\theta, m)$, and $a'(\theta, m)$ are solve the firm's Bellman equation, (3) Goods market clears

$$Y = \int c(\theta, m) dF(\theta, m) + C_w$$

(4) Asset Market Clears

$$B_w + \int a'(\theta, m) dF(\theta, m) = 0$$

(5) Labor Market Clears

$$L_w = \int I'(\theta, m) dF(\theta, m)$$

(6) Distribution $F(\theta, m)$ is consistent with firm policies

I assume that $\beta < \beta_w$, therefore in equilibrium $r = \frac{1}{\beta_w} - 1$. By Walras law, Y and W which clear goods and labor markets will automatically clear the asset market.

3 Quantitative Analysis

In this section, I present the quantitative results of the model.

3.1 Calibration

The model is calibrated at an annual frequency using cross-sectional information on stock-out rates from the literature and moments on sales and inventories from Compustat. First, some parameters are fixed and presented in Table 1. The elasticity of demand $\sigma = 3$, following [Hsieh and Klenow \(2009\)](#). The interest rate $r = 0.02$ to reflect low interest rates in the United States since 2000. This implies that $\beta_w = 0.98$. I set coefficient of relative risk aversion $\gamma = 2$ and the inverse Frisch elasticity of labor $\eta = 2$. The disutility of labor Ψ is set such that aggregate labor is 0.6. Finally, the persistence of demand is $\rho = 0.794$ using the annualized persistence of TFPR estimate from [Foster et al. \(2008\)](#).

Remaining parameters are chosen to match moments drawn from data. Remaining parameters to calibrate are the discount rate of firms, β , the depreciation rate of inventories δ_I ,

Table 1: Fixed Calibrated Parameters

Parameter	Value	Description	Source
σ	3	Demand Elasticity	Hsieh and Klenow (2009)
β_w	0.98	Worker’s Discount Factor	2% annual interest rate
γ	2	Risk Aversion	–
ρ	0.794	Persistence of $\log \theta$	Foster et al. (2008)
η	0.5	Inverse Frisch Elasticity	Arellano et al. (2019)
Ψ	1.78	Labor Disutility	$L_w = 0.6$

Table 2: Fitted Calibrated Parameters

Parameter	Value	Description
β	0.87	Firm’s Discount Factor
δ_I	0.95	Inventory Depreciation Rate
σ_θ	0.09	Std. of $\log \theta$
$\tilde{\sigma}_\theta$	0.75	Std. of $\log \theta$
$1 - \chi$	0.25	Prob. of bad state

Table 3: Targeted Moments

Moment	Model	Data
Gini	0.72	0.78
Stock-out Rate	0.69	0.72
$SD(\% \Delta p \cdot y)$	0.31	0.29
$SD(\% \Delta I)$	0.34	0.40
$Corr(\% \Delta I, m)$	0.64	0.68

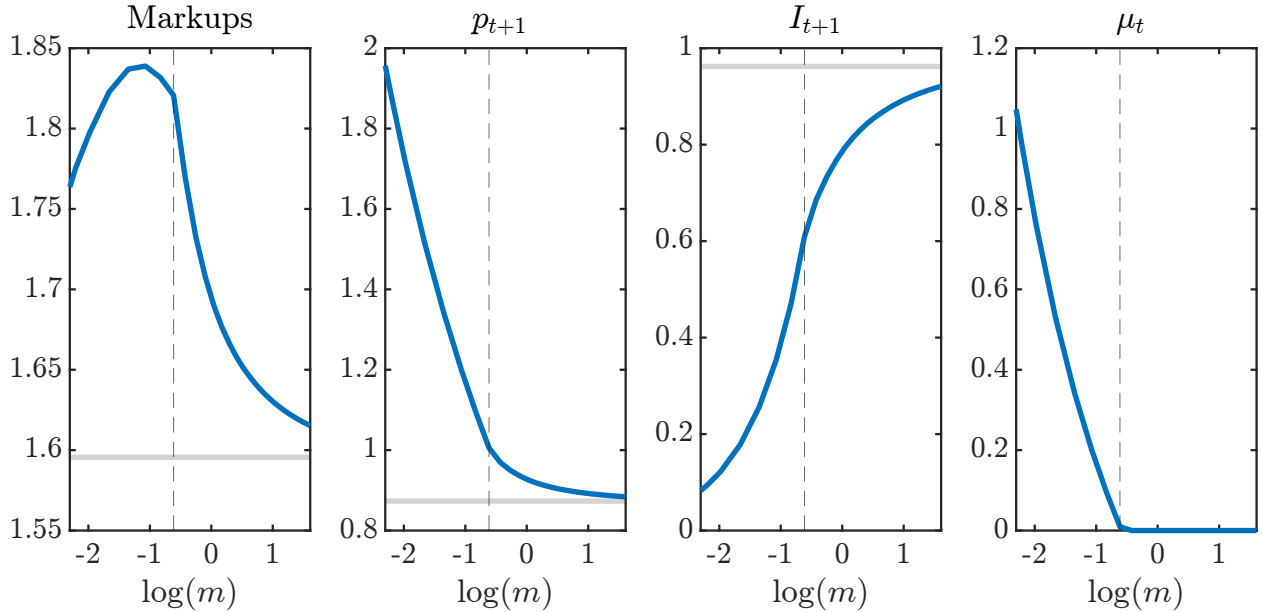
and moments governing demand shocks (σ_θ , $\tilde{\sigma}_\theta$, and χ). I choose these parameters to match moments capturing the volatility of sales and inventories, propensity for firms to stockout of inventories, and the inequality in wealth amongst firms: To capture inequality I target a gini coefficient of wealth of 0.78 for entrepreneurs in the US from [Boar and Midrigan \(2023\)](#). To capture volatility of sales and inventories, from Compustat, I target the standard de-

viation of annual sales and inventory growth. Also from Compustat, to capture how risk effects inventory accumulation through wealth, I target the correlation between inventories and cash.

Lastly, I need a target moment for stock-out rates. [Cavallo and Kryvtsov \(2023\)](#) document during COVID-19 pandemic a weekly stockout rate for US retailers in a number of product categories. The weekly stock-out rates range from 2-percent to 10-percent for the pre-crisis trend, which I treat as the long-term average. Since I model slower moving inventories, extending this rate to annualized frequency risks biasing results. I assume that stock-out rates are constant within a quarter and that firms are flexible after quarter. They either liquidate inventories or draw them down completely. The target stock-out rate then is the weekly rate reported at a quarterly frequency, that is $0.02^{1/12} = 0.72$ or 72 percent of firms experience a stock-out. [Table 2](#) presents values for these parameters. [Table 3](#) presents the model's moments from simulation and compares them to the targets.

3.2 Firm Policies

Figure 1: Firm Policies for Median θ



Prices and Inventories. Figure 1 plots firm policies for markups, prices, and inventories and the multiplier on the borrowing constraint in the last panel. This is plotted for the median θ and against cash on hand m . The vertical dashed line identifies the level in m

where $\mu_t > 0$. To the left of the line $a' = 0$ and the right $a' > 0$. The horizontal gray lines are the policies of the risk neutral firm facing the same equilibrium prices.

Inventories are significantly low for firms in a financially poor state. For firms with binding constraint, the gap to the complete insurance policy is significant. However, as firms face uninsurable risk, inventory policy is far from the complete insurance level for levels of cash on hand where they are not presently financially constrained. This occurs because investment in inventories is risky. Not only is output volatile but because of the timing surpluses in inventories lead to significant downside risk.

Second, note that prices are higher for low cash-on-hand firms and prices. In addition, prices are higher than if set with complete insurance. The variation in prices is greater when $\mu_t > 0$. As cash on hand increases, prices fall towards the complete insurance counterfactual. However, there is still a significant gap. This occurs because risk of stock-outs or borrowing constraint binding in the future is very costly.

Risk Markups. Markups are significantly higher for risk averse firms than the complete insurance benchmark. Markups increase with respect to cash on hand but then fall when the a firm is no longer bound by the no borrowing constraint. Markups in the this environment are a consequence of risk. Firms with greater levels of demand, θ , will face relatively more downside risk, all else equal. Therefore, we can understand the nature of precautionary behavior in this model by comparing policies for different θ and the associated covariances between marginal utility, stock-outs, and utilization.

Figure 2: Firm Policies Relative to Full Insurance Benchmark for By θ

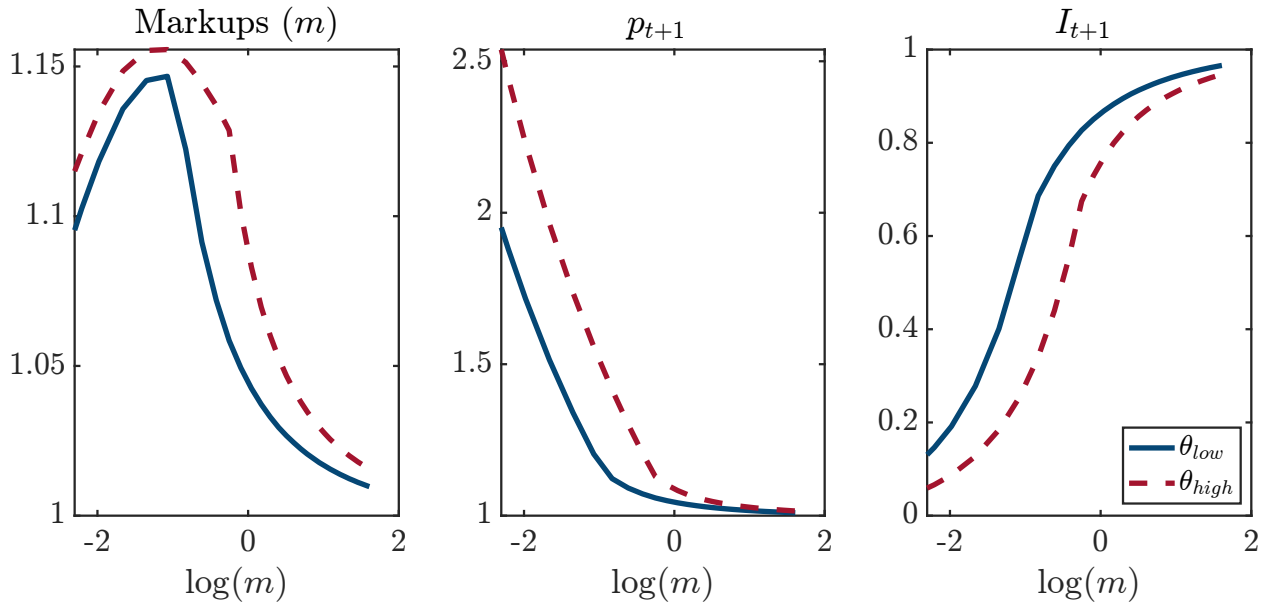


Figure 2 plots the policies for two different levels of θ relative to the complete insurance benchmark. Note that prices and markups increase, and inventories decrease, as θ increases. Since sales are greater with greater θ , the model still preserves what is sometimes termed "Marshall's Second Law." Nonetheless, markups increase with θ not because demand becomes more inelastic but because precautionary behavior.

To understand the role of precautionary behavior generating markups, recall markups are $\frac{\hat{\sigma}}{\hat{\sigma}-1}$ where

$$\begin{aligned}\hat{\sigma} &= \sigma \frac{\widehat{\mathbb{E}}(y'|y' \leq I')}{\widehat{\mathbb{E}}(\min\{y', I'\})} \\ &= \sigma \frac{\widehat{\mathbb{E}}\left(\frac{y'}{I'}|y' \leq I'\right)}{\widehat{P}(y' \geq I') \left\{1 - \widehat{\mathbb{E}}\left(\frac{y'}{I'}|y' \leq I'\right)\right\} + 1}\end{aligned}$$

Very importantly, the elasticity of substitution varies depending on two margins. First, the extensive margin $\widehat{P}(y' \geq I')$, the ex-ante probability of stock-outs under the risk neutral measure. Second, the intensive margin $\widehat{\mathbb{E}}\left(\frac{y'}{I'}|y' \leq I'\right)$, the expected utilization rate of inventories, also under the risk neutral measure.

Expressing these two margins without the risk neutral measure:

$$\begin{aligned}\widehat{P}(y' \geq I') &= P(y' \geq I') + Cov\left(\frac{u'(c')}{\mathbb{E}(u'(c'))}, \mathbb{I}(y' \geq I')\right) \\ \widehat{\mathbb{E}}\left(\frac{y'}{I'}|y' \leq I'\right) &= \mathbb{E}\left(\frac{y'}{I'}|y' \leq I'\right) + Cov\left(\frac{u'(c')}{\mathbb{E}(u'(c'))}, \frac{y'}{I'}\right)\end{aligned}$$

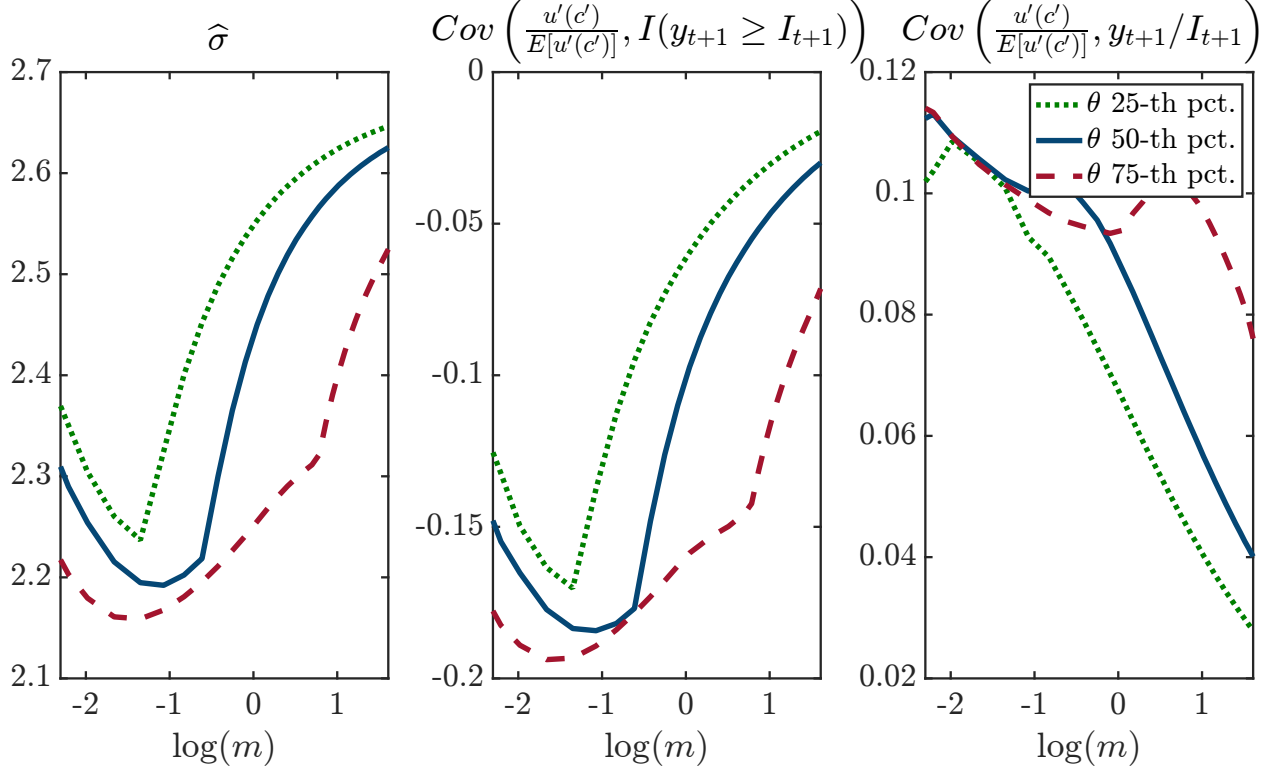
The extensive margin is associated with risk when stock-outs are more likely to occur in states with high marginal utility of consumption. Intuitively, in states where consumption is valuable the opportunity cost of missed profits due to setting prices in retrospect too low or producing too little inventories is costly. In such cases, $Cov\left(\frac{u'(c')}{\mathbb{E}(u'(c'))}, \mathbb{I}(y' \geq I')\right) > 0$. This increases $\widehat{P}(y' \geq I')$, lowering the elasticity of demand and hence increasing markups. The risk in this margin comes from missing out of valuable sales and rationing demand.

The intensive margin reflects risk if utilization rate of inventories is low. This margin reflects risk from carrying surplus inventories. Inventories are risky as bad shocks in demand will lead to inventories unsold and liquidated at significant discounts relative to costs. This risk is reflected by $Cov\left(\frac{u'(c')}{\mathbb{E}(u'(c'))}, \frac{y'}{I'}\right) < 0$. Thus, if low utilization coincidences with bad states for the firm, the expected utilization rate under the risk neutral measure is lower. This drives markups higher, all else equal.

These margins are irrelevant under complete insurance, however the risk averse manager

internalizes them. Therefore, evidence of risk aversion will be avoidance of stock-outs when cash on hand, m is low, and/or an increase in utilization. Figure 3 plots the elasticity of demand and the two covariance of interest.

Figure 3: Elasticity of Demand and Risk for By θ



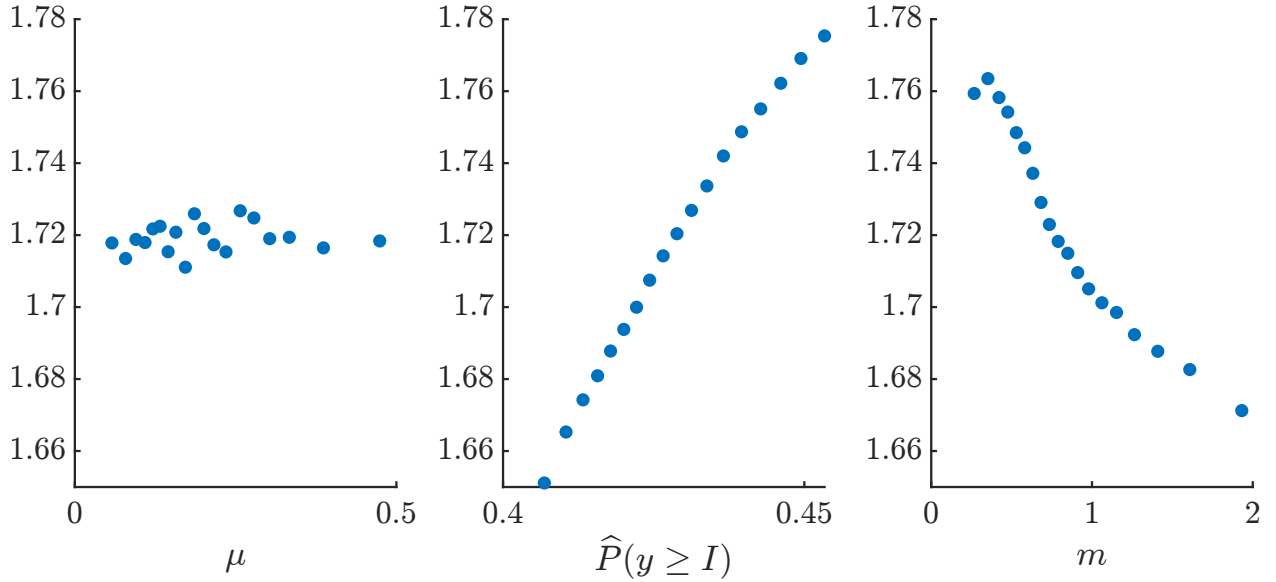
In attempting to deal with the covariance of utilization and stock-outs with marginal utility, the firm faces a trade-off. If they reduce expected stock-outs in bad states, they invariably reduce expected utilization and vice-versa. Therefore, results in Figure 3 suggests that firms increase their markups in low risk states by increasing their utilization. As risk increases, presented in Figure 3 as θ at the 75-th percentile, the covariance of marginal utility with stock-out falls and so does the covariance with utilization. Hence, the firm moves in the direction of policy that takes relatively greater precaution against stock-outs versus slack capacity.

In summary, precautionary behavior in their environment generates markups. These markups are informative about two sources of risk. First, along the extensive margin, risk of rationing or stocking-out of inventories. Hence, hence missing out on profits. Second, along the intensive margin, the risk of unsold inventories. As the firm's level of risk increases, precautionary behavior moves from self-insurance against intensive margin risk to extensive margin.

Financial Frictions. The borrowing constraint, $a' \geq 0$ plays a role in firm policies. Note that monotonicity of markups changes around the vertical dashed line in Figure 1. Marginal cost of inventories for a firm is $W(1+r+\mu)$. The multiplier on the no borrowing constraint, μ , varies across firms and in particular across cash-on-hand, m . From the definition of markups, holding costs constant, all deviations from the complete insurance benchmark is due to covariance of stock-out and output with marginal utility. Hence, contemporaneous financial frictions do not effect markups. The non-monotonicity of markups around when μ becomes positive reflects a change in the main distortion faced by firms. As the financial wealth of firms increases, the cost of financial frictions falls and prominence of risk as the main distortion rises. Idiosyncratic risk faced by firms is highest when $\mu = 0$. Firms have CRS production but face CES demand. In this environment, markups have similar implications as the risk wedge in Boar et al. (2022) and Di Tella et al. (2025), where firms are perfectly competitive but have DRS production.

Cross-section. To confirm contemporaneous financial frictions are not crucial for markup dispersion, in Figure 6 I plot binscatters of markups as a function of μ , the multiplier on the no-borrowing constraint, $\hat{P}(y' \geq I')$ the stock-out rate, under the risk neutral measure, and cash-on-hand. In the ergodic distribution, there is very little variation in markups across μ . Instead, significant variation occurs across firms with different stock-out rates and financial wealth.

Figure 4: Markups Binscatter



3.3 Consequences for Productivity

In this section, I present results of the misallocation decomposition in equation (XX):

$$\begin{aligned}
\underbrace{\log\left(\frac{Z_{t+1}^*}{Z_{t+1}}\right)}_{2.80\%} &\approx \underbrace{\mathbb{E}\left(\log\frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})}\right)}_{11.07\%} + \underbrace{\mathbb{E}(\log(1 + \xi_{i,t}))}_{-8.49\%} \\
&\quad + \underbrace{\frac{1}{2}\left[\mathbb{V}ar\left(\log\frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})}\right) + \mathbb{V}ar(\log(1 + \xi_{i,t}))\right]}_{0.11\%} \\
&\quad - \underbrace{\mathbb{C}ov\left(\log\frac{\mathbb{P}^*}{\hat{\mathbb{P}}(y_{i,t+1} \geq I_{i,t+1})}, \log(1 + \xi_{i,t})\right)}_{-0.11\%}
\end{aligned}$$

As predicted above, the two margins have opposing implications for misallocation. Losses as a consequence of risk are 2.8 percent. The gap in stock-out rates contributes 11 percent loss. This is a significant amount and is counter-acted partially by the intensive margin, $\xi_{i,t}$, which reduces misallocation by 8.5 percent. The second order effects are small. A significant implication of this outcome is that misallocation is generated primarily by sub-optimal stock-out rates of risk averse firms. Since running out of inventories is costly, especially as exposure to idiosyncratic risk increases, the probability of stock-outs falls. The lower stock-out rates are generated by higher prices, lower inventory demand, and greater markups.

3.4 Consequences of Inflexible Prices

So far, I have shown that risk is a significant source of misallocation. An important reason is that because prices and inventories are chosen in advance firms are subject not only to the risk of too little demand, but potentially if prices are too low, to missing out on high levels of demand. To investigate this further I compare the model to one where firms choose inventories, I' , and commit ex-post to the market clearing price to sell all inventories. This is the canonical monopolistic pricing model. One can interpret this as a model with labor chosen one period in-advance. Prices if I' are the inventories:

$$p' = (\theta')^{\frac{1}{\sigma}} \left(\frac{I'}{Y}\right)^{-\frac{1}{\sigma}}$$

The optimal inventories solve:

$$I' = \left[\frac{\widehat{\mathbb{E}} \left[\theta_{t+1}^{\frac{1}{\sigma}} \right] Y^{\frac{1}{\sigma}} \left(1 - \frac{1}{\sigma} \right)}{W(1 + r + \mu)} \right]^{\sigma}$$

This implies that under optimal policy, expected prices are

$$E(p') = \frac{\sigma}{\sigma - 1} W(1 + r + \mu)$$

Unlike the case with predetermine prices, the expected price will be a constant markup over marginal cost. In Figure 5, I compare policies the benchmark and with flexible pricing. In the flexible price model, I plot expected prices as they vary with realized demand. Note that the policies are very similar when financial frictions are binding but are significantly different when they do not. When $\mu = 0$, the budget constraint of the firm becomes $c \leq m - WI'$. Therefore, since consumption will be very low in these states inventories levels will be quite close to the available cash-on-hand.³

Outside of $\mu > 0$, the policies are significantly different. The expected price becomes identical for all firms under flexible pricing. In addition, there is a significant jump in inventory demand. In fact, with risk aversion and flexible pricing, a firm demands more inventories and plans to sell them at lower prices than the complete insurance counterfactual with one-period ahead pricing.

4 Empirical Analysis

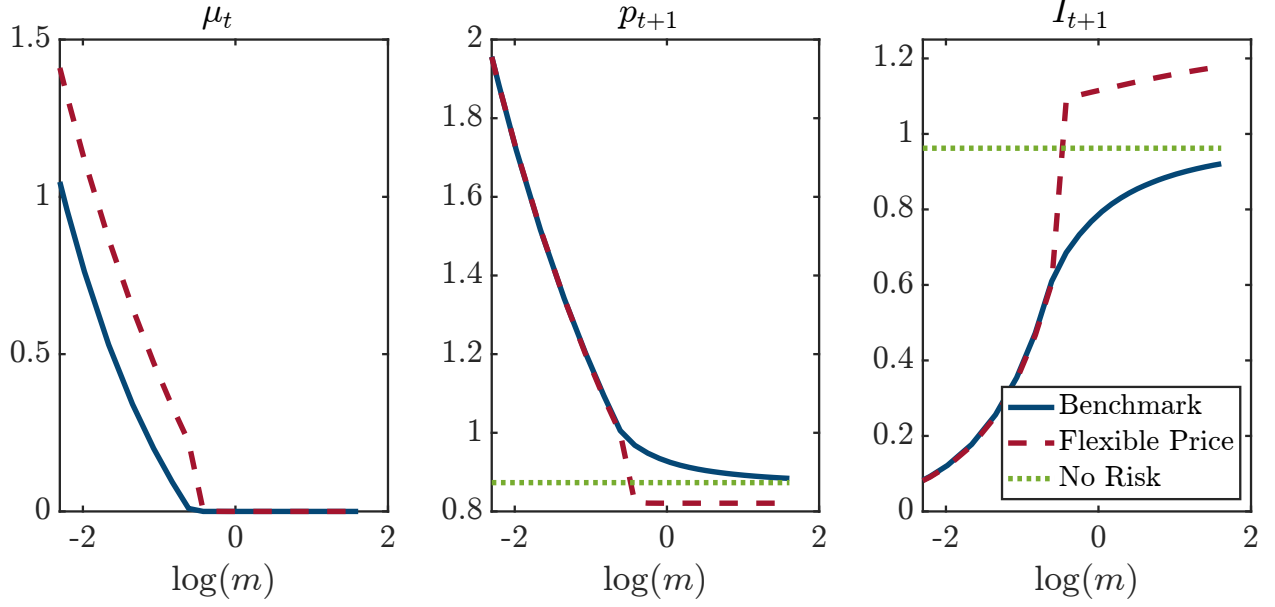
In this section, I validate firm behavior implied by the model. The model implies that uninsurable risk leads to higher prices, higher markups and lower inventory investment. Using balance sheet data for US non-financial corporations between 2006 and 2019, I will show that firms facing greater idiosyncratic risk have lower inventory investment. Moreover, variation in exposure to idiosyncratic risk explains a significant share of markup variation in the cross-section. A model without risk averse firms would not be successful in replicating the data, as markups would not vary and inventory demand is unrelated to demand volatility.

4.1 Data

Volatility. Following Gilchrist et al. (2014) and Panousi and Papanikolaou (2012), I proxy idiosyncratic uncertainty with the volatility of residual excess returns of the firm's

³Under linear preferences with $c \geq 0$, they would exactly equal cash-on-hand.

Figure 5: Compare Firm Policies to Flexible Counterfactual for Median θ



stocks. Data from returns on stocks comes from the Center for Research on Stock Prices (CRSP). I observe end of week returns from first week of 2001 until last week of 2022. I restrict attention to non-financial firms. Let $r_{i,t}^x$ be the return on the stock of firm i at week t . Define $r_{m,t}^x$ as the market excess return and $r_{s,t}^x$ as the sector average excess return.⁴ I estimate the following:

$$r_{i,t}^x = \alpha_i + \beta_{m,i} r_{m,t}^x + \beta_{s,i} r_{s(i),t}^x + \varepsilon_{i,t}$$

Define

$$\sigma_{i,t} = \sqrt{\frac{1}{\tau_D} \sum_{\tau \in t} (\hat{\varepsilon}_{i,\tau} - \bar{\varepsilon}_{i,\tau})^2}$$

as the standard deviation of residuals in the excess return in quarter t , where τ_D is the number of trading weeks in quarter t . I use $\sigma_{i,t}$ as a measure of idiosyncratic returns net of predictable components. It reflects variation in equity returns unrelated to the business cycle, sector, or trend. High levels of $\sigma_{i,t}$ reflects high idiosyncratic uncertainty.

Balance Sheet. From Compustat Fundamentals Quarterly, I compute measures of investment in physical capital and inventories. As in returns data, I restrict attention to non-financial firms and observations between 2001:Q1 to 2022:Q4. I measure physical capital using inventory method. I define inventories as total inventories, that is the measure includes inventories in final goods, materials used in production, and goods in progress of

⁴Sector is defined at the 3-digit NAICS level.

manufacturing.

Executive Ownership. As firms in the sample are publicly traded, decision makers such as firm executives are not necessarily as exposed to volatility in returns as they may not be owners in their firm’s stock. Firms in the model I present are the only owners of the equity. Following [Panousi and Papanikolaou \(2012\)](#), I use a Compustat supplemental on executive ownership to identify firms with managers with ownership stake in their employer. Public firms must report the ownership stake of their executive officers to the Securities Exchange Commission. Define $S_{i,t}$ as the share of outstanding stock owned by executives. Due to data quality, only data from 2006 to 2019 is available for executive ownership.

Summary Statistics. Table 4 presents summary statistics for the merged panel of firm volatility with balance sheet and ownership information. I assume that executive ownership is constant within a year. Overall, 50 percent of of firm-quarter observations have executives with stock ownership, i.e. $S_{i,t} > 0$. Executives own on average 3 percent of stocks. Note that at the 90th, 95th, and 99th percentiles the values for $S_{i,t}$ are 7, 13, and 35 percent respectively. There is significant dispersion and skewness in executive ownership.

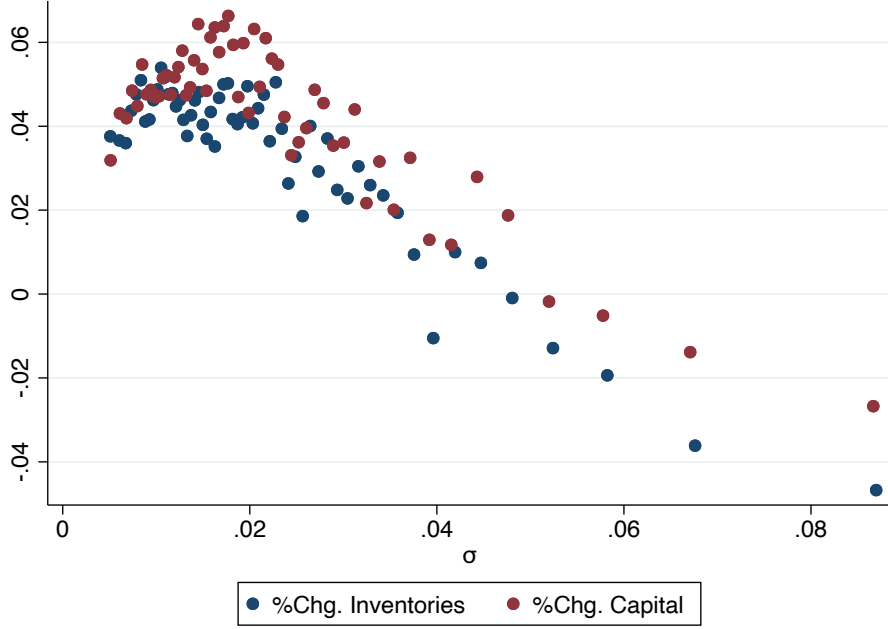
Table 4: Summary Statistics

Variable	Mean	SD	25th pct	Median	75th pct
$\frac{\Delta_{4\text{inv}t}}{\text{assets}}$	0.03	0.22	-0.08	0.03	0.15
$\frac{\Delta_{4k}}{\text{assets}}$	0.04	0.23	-0.05	0.01	0.10
$\log(\sigma)$	-3.96	0.62	-4.40	-3.98	-3.53
S	0.03	0.06	0.00	0.01	0.02

4.2 Findings

I report two results: (1) high volatility in excess returns dampens inventory investment and more so for firms with shareholder executives and (2) volatility in excess returns and shareholder ownership explain 5 to 20 percent of markup dispersion. The first observation point to the relevance of risk aversion for inventory investment. Final observation motivates the focus on markups arising due to risk. The two facts together validate the modeling of pricing and output decisions.

Figure 6: Annual Inventory and Capital Growth against $\sigma_{i,t}$



Inventories and Risk. In Figure 6, I plot binscatter of annual inventory investment, defined as $\log(\text{inv}_{i,t}) - \log(\text{inv}_{i,t-4})$, and annual physical capital investment, defined as $\log(k_{i,t}) - \log(k_{i,t-4})$, on idiosyncratic uncertainty.⁵ Notice that as firms face more uncertainty investment falls for both inventories and physical capital. To illustrate the relevance of risk for investment inventories more carefully, I estimate the following specification:

$$\log(\text{inv}_{i,t}) - \log(\text{inv}_{i,t-4}) = \alpha_{s(i)} + \alpha_i + \alpha_t + \beta \log \sigma_{i,t} + \gamma \mathbb{I}(S_{i,t} > 0) \log \sigma_{i,t} + \Gamma' X_{i,t} + \varepsilon_{i,t}$$

I regress an outcome variable on log volatility $\sigma_{i,t}$ and interaction between log volatility and indicator variable for executive ownership. I include sector, firm, and time fixed-effects. I also include firm specific controls in vector $X_{i,t}$. In addition to inventory growth, I also regress annual capital investment rate on the same explanatory variables. Table 5 presents the regression results. Note that higher volatility is associated with lower inventory investment. As observed by Gilchrist et al. (2014), capital investment is dampened. More importantly, interaction between volatility and executive ownership dampens inventory investment. Therefore, firms with lots of idiosyncratic risk, for which their managers are also exposed will have lower inventory investment rates. This result extends the findings in Panousi and Papanikolaou (2012) to inventories. Overall, risk aversion can explain the

⁵Physical capital is measure via the perpetual inventory method.

cross-sectional variation in inventory accumulation.

Table 5: Panel Regressions

	Capital	Inventories
$\log(\sigma)$	-0.019*** (0.002)	-0.011*** (0.002)
$\log(\sigma)$ and $S > 0$	-0.005*** (0.001)	-0.006*** (0.001)
Controls	$\log(\text{sales}), \log(\text{inv.})$	$\log(\text{sales}), \log(\text{inv.})$
N	69719	70359
R^2	0.31	0.37

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Markups and Risk. The model suggests that markups are due to risk. I have abstracted from sources due to imperfect competition or variable demand elasticity. Next, I illustrate that nonetheless variation in risk explains a significant share of dispersion in markups. Measuring markups from using only revenue and cost data is fraught as noted by [Bond et al. \(2021\)](#). However, we can still use ratio of sales to cost-of-goods-sold (COGS) from Compustat to recover sectoral markup dispersion. This is done under the assumption that output elasticities within sectors are identical.⁶ Dispersion in log sales to COGS is the dispersion of markups within a sector.

To decompose the dispersion, I run the following fixed-effect regression:

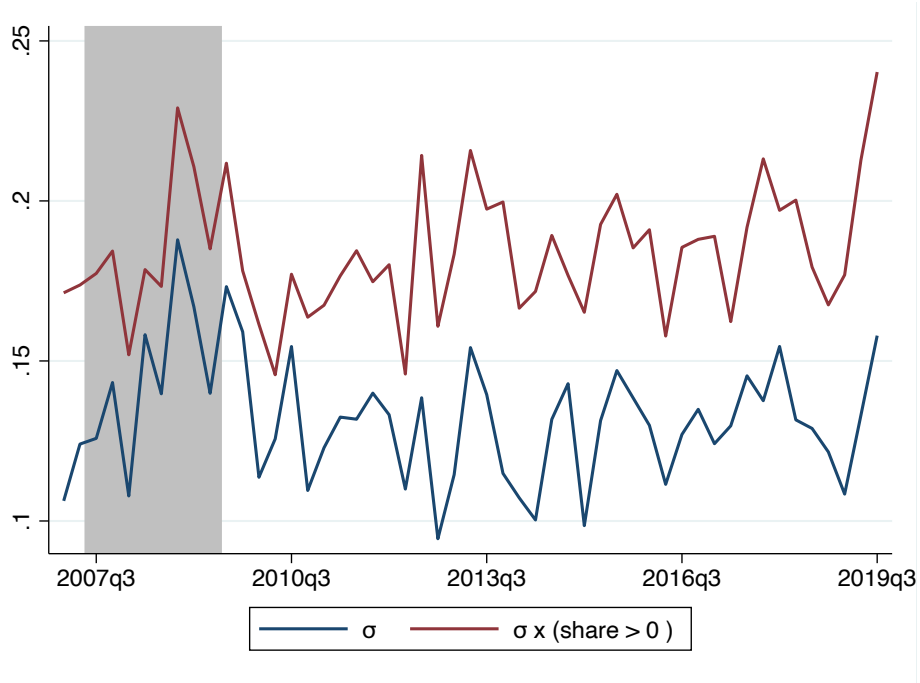
$$\log\left(\frac{\text{sales}_{i,t}}{\text{cogs}_{i,t}}\right) = \alpha_{s(i)} + \alpha_t + \alpha_{\sigma,t}(i) + \varepsilon_{i,t}$$

This regression takes out the sector and time fixed-effects, as in the specification above. In addition, $\alpha_{\sigma,t}(i)$, identifies the quintile in $\log \sigma_{i,t}$ that the firm belongs at time t . Figure 7 plots standard deviation of $\alpha_{\sigma,t}(i)$ relative to standard deviation of $\log\left(\frac{\text{sales}_{i,t}}{\text{cogs}_{i,t}}\right)$ overtime.⁷ In addition, I include same fixed-effect for $\log \sigma_{i,t}$ but also interacted with $S_{i,t} > 0$, i.e. identifying exposed executives. Note that volatility of returns, and especially when they are interacted with exposure of executives, explains between 10 to 25 percent of markup dispersion.

⁶[Meier and Reinelt \(2024\)](#) measure markup dispersion similarly.

⁷Due to restrictions on markup estimation from balance-sheet data, dispersion is conditioned within a sector.

Figure 7: Markup Dispersion Explained by Risk



5 Risk and Supply Chain Crisis

In this section, I use the model to study the implications of supply chain crises. In the COVID-19 pandemic, and its aftermath, disruptions to the supply chain impacted prices, markups, and stock-out rates.⁸ According to the United States International Trade Commission, at the peak of the pandemic 20 percent of shipments by major container shipping firms were canceled.⁹ The Census Bureau reports in the Small Business Pulse Survey, which surveys firms weekly between 2020 and 2022, that at the outset of the pandemic 40-percent of firms experienced delays in deliveries from foreign and domestic suppliers.¹⁰ This level persists throughout the survey's duration, fraction of firms reporting delays ranges between 39 and 65 percent between 2020 and 2022.

In the context of my environment, I model supply chain crisis as an increase in portion of inventories that are canceled. Formally, let $\lambda_t(\theta, m)$ be the share of inventories that fail

⁸On stock-outs and prices see [Cavallo and Kryvtsov \(2023\)](#), on markups see [Alvarez et al. \(2025\)](#).

⁹Report accessible at: https://www.usitc.gov/research_and_analysis/tradeshifts/2020/special_topic.html.

¹⁰Survey accessible at: <https://portal.census.gov/pulse>.

to arrive at time t for a firm in with demand θ and cash on hand m , where

$$\lambda_t(\theta, m) = \begin{cases} \lambda_t & \text{with prob. } \eta \\ 0 & \text{otherwise} \end{cases}$$

At the beginning of period t the firm fails to receive $\lambda_t \in [0, 1]$ of their previously ordered inventories with probability η . Exposure to the supply chain crisis is identically and independently distributed across firms and time. While exposure to the crisis is drawn independently by firms, the severity of the crisis, λ_t , is a common shock.¹¹ The down payment for failed deliveries is returned to the firm, with the interest accrued between periods.¹²

Two parameters are introduced rather than one to capture the risk generated by a supply chain crisis. If λ_t effects all firms with certainty, this setting is isomorphic to one where inventories are taxed at rate λ_t . This does not capture the crucial feature of supply chain crisis, crisis leads to an increase in idiosyncratic uncertainty for firms. This shock is motivated by the literature on shipping delays and international trade.¹³ Note that this setting is close to models with uncertainty shocks.¹⁴ Rather than have uncertainty shocks changing productivity or demand uncertainty, λ_t implicitly increases the idiosyncratic uncertainty firms are exposed to through stock-outs and low utilization. As was emphasized in previous sections, uncertainty through these sources is critical for understanding pricing behavior of firms.

The first order condition for prices remains unchanged as the shocks to inventory delivery are conveniently subsumed into the expectations operator. On the other hand, optimal inventory choice changes

$$\begin{aligned} \left((1 + r_{t+1})(1 - \tilde{\lambda}_{t+1}) + \mu \right) W_t = & \left(1 - \tilde{\lambda}_{t+1} \right) \hat{\mathbb{E}}_t [\mathcal{X}_{t+1} p' + (1 - \mathcal{X}_{t+1})(1 - \delta_I) W_{t+1}] \\ & - \hat{\text{Cov}}_t (\lambda_{t+1}(\theta', m'), \mathcal{R}_{t+1}) \end{aligned} \quad (6)$$

where as before $\mathcal{X}_{t+1}$ is an indicator of stock-out and

$$\mathcal{R}_{t+1} = \mathcal{X}_{t+1} p' + (1 - \mathcal{X}_{t+1})(1 - \delta_I) W_{t+1}$$

¹¹To be clear, in the steady state $\lambda_t = 0$ and hence η as a parameter is irrelevant. Alternatively, a baseline severity (λ_0) and exposure (η) could be included in an alternative calibration of the steady state.

¹²Firms are refunded $W_{t-1} I_t \lambda_t(\theta, m)(1 + r_t)$.

¹³For instance, [Alessandria et al. \(2023\)](#) make the probability of delays in shipments a random variable that is subject to fluctuations.

¹⁴Examples of papers with uncertainty shocks: [Di Tella \(2017\)](#), [Bloom et al. \(2018\)](#), and [Di Tella and Hall \(2022\)](#).

This optimality condition is very similar with two new additions. First, $\tilde{\lambda}_{t+1} = \hat{\mathbb{E}}_t(\lambda_{t+1}(\theta', m'))$ is the average delivery failure rate for inventories under the risk neutral measure. Second, $\mathcal{R}_t$ is the marginal value of inventories, ex-post.

In equation (6), the right-hand-side reflects the marginal benefit of inventories. The supply chain crisis reduces marginal benefit of inventories in two ways: (1) The average shortfall in inventories $\tilde{\lambda}_{t+1}$ the firm expects, under their risk-neutral measure. (2) Covariance of delivery failure rates $\lambda_t(\theta, m)$ and the return to inventories. The former reflects the manner that supply shocks can appear as implicit taxes on inventories. Of course, such a tax is not uniform as $\tilde{\lambda}_{t+1}$ will vary across firms due to differences in expected marginal utility of consumption.

Prices in a supply chain crisis are the following:

$$p' = \underbrace{\frac{\tilde{\sigma}}{\tilde{\sigma} - 1}}_{\text{markup}} \underbrace{W_t \left((1 + r_{t+1})(1 - \tilde{\lambda}_{t+1}) + \mu \right)}_{\text{marginal cost}}$$

The marginal costs contains an adjustment for refunds if and when there is exposure to the crisis. Markups are a Lerner index again of expected elasticity of demand $\tilde{\sigma}$. However, the elasticity of demand is defined differently to emphasize the role of the supply chain crisis. This elasticity can be expressed that

$$\tilde{\sigma} = \hat{\sigma} \frac{1}{1 + \frac{\hat{\mathbb{E}}_t(\mathcal{X}_{t+1}\lambda_{t+1}(\theta', m'))}{1 - \hat{\mathbb{E}}_t(\mathcal{X}_{t+1})}} \quad (7)$$

If $\lambda_t = 0$, then $\tilde{\sigma} = \hat{\sigma}$, which is expressed as

$$\hat{\sigma} = \sigma \frac{\hat{\mathbb{E}}_t(y'|y' \leq (1 - \lambda_{t+1}(\theta', m'))I')}{\hat{\mathbb{E}}_t(\min \{y', (1 - \lambda_{t+1}(\theta', m'))I'\})}$$

This is the same expected elasticity of demand as expressed in equation (2). Relative to equation (2), I include terms for the possible short-fall in inventories. In equation (7), the supply chain crisis further reduces expected demand elasticity $\hat{\sigma}$ through the final term. This term is a function of the covariance of stock-outs and shock $\lambda_{t+1}(\theta', m')$. The more positively the correlation, the lower the expected elasticity of demand, from the perspective of the firm, and the greater the increase in markups, all else equal.

As the crisis increases risk for firms, the term $\hat{\sigma}$ will be lower relative to the steady state. This channel reflects the general manner in which increased idiosyncratic risk leads to higher markups. One can think of variation in markups due to $\hat{\sigma}$ as reflecting changes due to demand uncertainty. This increases in crises. The additional term in $\tilde{\sigma}$ reflects further

amplification due to the non-linearity of the shock and it's interaction with stock-outs. This reflects the increase in markups due purely due to risk generated by the supply chain crises and not its interaction with demand uncertainty.

Comparison to Flexible Pricing. Inflexible pricing is a significant source of risk for firms in supply chain crisis. To see this, in the flexible price counterfactual introduced in section 3.4, within the same type crisis, optimal inventories can be expressed as

$$I' = \left[\frac{\widehat{\mathbb{E}}_t \left[\theta'^{\frac{1}{\sigma}} (1 - \lambda_{t+1}(\theta', m')) \right] Y_{t+1}^{\frac{1}{\sigma}} \left(1 - \frac{1}{\sigma} \right)}{W_t((1+r)(1 - \tilde{\lambda}_{t+1}) + \mu)} \right]^{\sigma}$$

and prices remain on average with a markup of $\frac{\sigma}{\sigma-1}$, identical to the flexible markup under CES demand. Overall, the supply chain crisis maps to an increase in demand uncertainty. From this one can conjecture that a demand shock would produce similar results, with the caveat that it is a demand shock with heterogeneous effects. Hence, to capture the pure supply side effect of a supply chain crisis one ought to move beyond flexible pricing and give serious consideration to the consequences of price setting.

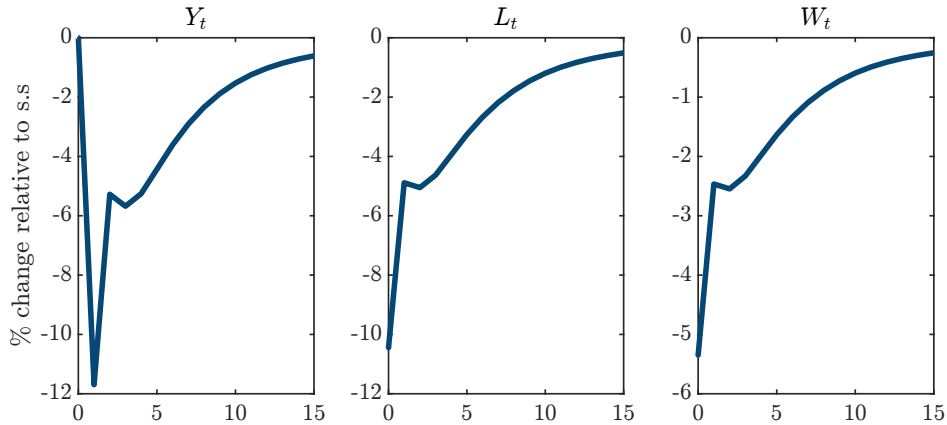
Timing. I will assume sequence of λ_t is known to firms. At $t = 0$, $\lambda_0 = 0$ and $\lambda_t > 0$ for $t > 0$ and $\lim_{t \rightarrow \infty} \lambda_t = 0$. Shocks are not unexpected on impact as this exercise isolates exactly the increase in idiosyncratic risk as a opposed to balance sheet effects. These are caused by failure of inventories to arrive at $t = 0$ which have only an effect on firms by reducing their net worth and mechanically reduce the stock-out rate. Since I focus on risk and stock-out rates increase I consider an anticipated crisis. Lastly, I will study a partial equilibrium response, I will fix interest rates and only the goods and labor market will clear. I want to emphasize the results below are reflective of one particular industry or a small open economy.

Calibration. I choose $\eta = 0.40$ based on the share of firms in the Census' Small Business Pulse Survey reporting delays to shipments from either domestic or foreign suppliers. I choose $\lambda_0 = 0.5$ such that on average 20 percent of shipments do not arrive, to match the peak figure in the USITC report. Finally, I assume $\lambda_{t+1} = \rho_{\lambda} \lambda_t$ and choose $\rho_{\lambda} = 0.63$ such that half-life of the crisis is 1.5 years.

5.1 Benchmark Results

Figures 8 plot the path of output (Y_t), inventories (L_t), and wages (W_t), in percentage points relative to the steady state. The crisis implies significant losses for output. In addition, workers producing inventories suffer as a consequence of the fall in wages. The fall in inventories is also significant, implying that stock-out rates are likely to increase throughout the crisis. This is confirmed in the next panel of figures.

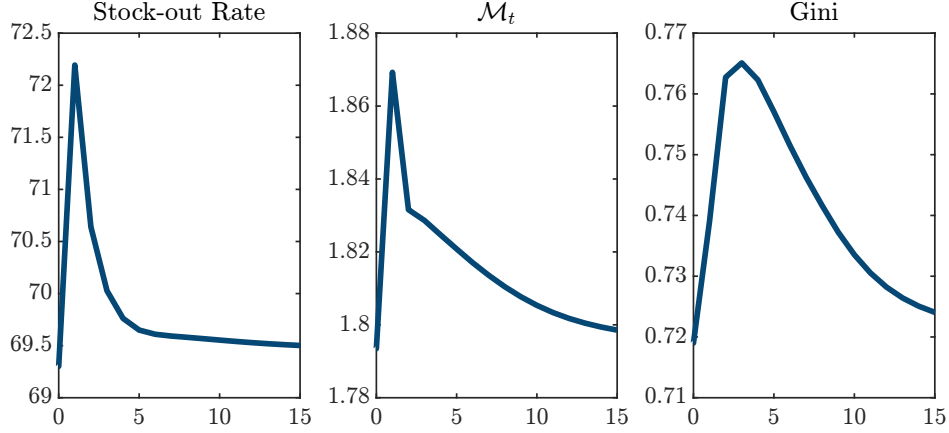
Figure 8: Response of Output, Inventories, and Wages



In Figures 9, the path of stock-out rates, aggregate markup $\mathcal{M}_t$, and gini coefficient of wealth among firms is plotted. As noted, the crisis leads to an increase in stock-outs, by 5 percent at the peak, as was initially calibrated with λ_t . This stock-out increase coincides with an increase in markups, the aggregate markup increases from 1.79 to 1.87. Also inequality worsens, the gini-coefficient increases from 0.72 to 0.76. As the wealth distribution through risk compensation via markups determines the aggregate markup, one can conjecture that the magnitude of the effects on markup and output are likely amplified by the wealth heterogeneity. In fact, stock-out rates return quickly to the steady state values relative to the aggregate markup, which remains persistently above the steady state level similarly to the gini coefficient.

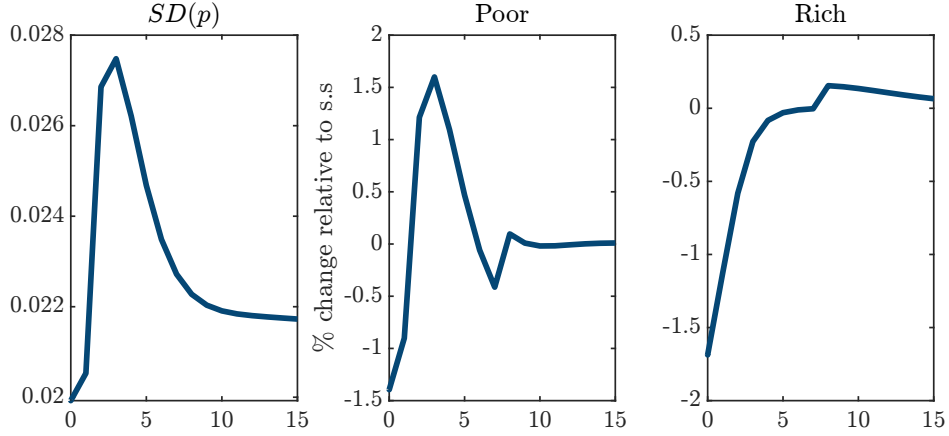
In Figures 10, to study the behavior in the cross-section, I plot the standard deviation of prices and the average price policy by poor and rich firms. I define poor firms as those who are at the borrowing constraint, that is $a' = 0$. Rich firms are otherwise financially unconstrained, $a' > 0$. At the peak effect of the supply chain crisis prices become extremely dispersed. I find that poor firms adjusted prices upwards during the crisis on average and wealthy firms have relatively flat responses. Much of the price dispersion is being driven by the differential wealth of firms. This illustrates the manner in which pricing can be used as a precautionary measure. The poor firms care about stock-outs quite significantly as their

Figure 9: Response of Stock-out Rates, Markups, and Gini



inventory demand is already significantly restricted. Therefore, they want to insure the high degree of profits in bad states of the world. Wealthy firms behave closer to risk-neutral firms, their pricing policy reflects greater responsiveness to the aggregate state. Expecting a fall in output, they lower their price. All firms on impact have lower prices to reflect the aggregate output, Y_t falling and shifting demand everywhere lower.

Figure 10: Average Price for Poor and Wealthy Firms



5.2 Counterfactuals

In this section, I consider two counterfactual exercise to understand the role of risk and pre-determined price setting for outcomes in a supply chain crisis. To understand the role of risk, I will repeat the exercise for an economy with risk neutral firms without any financial frictions. To understand the consequences of price setting in the benchmark economy, I repeat the crisis in an economy with flexible pricing, keeping preferences and financial fric-

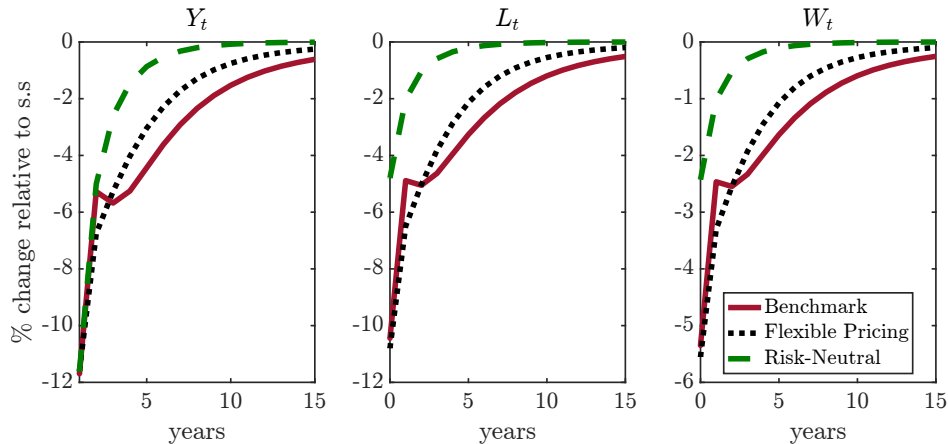
tions untouched. For each counter-factual, I re-calibrate λ_t such that peak impact on Y_t is identical to the benchmark response.

Table 6: Counterfactual: Steady States

	Benchmark	Risk-Neutral	Flexible Pricing
Y	0.58	36%	34%
Z	0.98	1.2%	5%
$\mathcal{M}$	1.79	-4.0%	-7%
Stock-out	69%	61%	—
Gini	0.72	—	20%

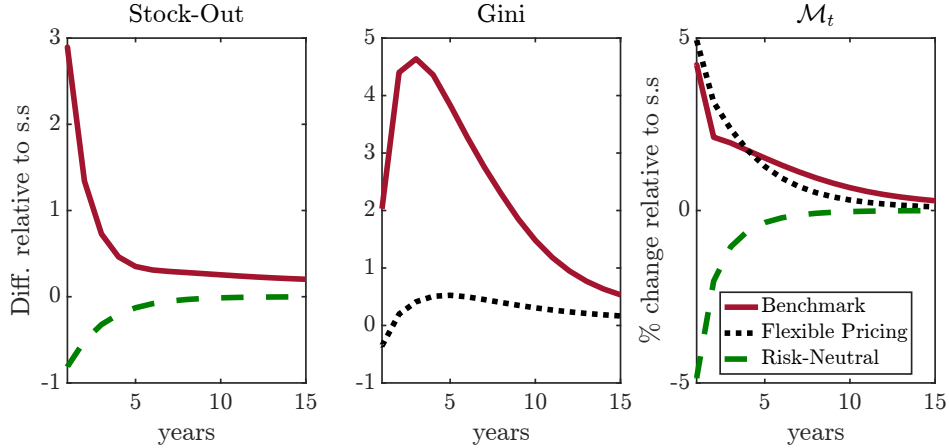
To begin with, I compare the steady state properties of the different environments in Table 6. The first column presents values for the moments of interest in the benchmark economy and the subsequent columns present the percentage difference with the counterfactual economy. Both risk neutral and flexible price economies have significantly higher output. This is owed primarily to greater aggregate productivity and lower aggregate markups. This is a consequence of the role of risk in the benchmark economy. For the supply chain crisis, Figure 11 compares the path of output, inventories, and wages for the benchmark economy and the two counterfactual exercises. Figure 12 compares the stock-out rates, gini coefficient, and aggregate markups across models.

Figure 11: Counterfactual: Response of Output, Inventories, and Wages



Compare to Risk Neutrality. From Figure 11, I observe that risk leads to more pronounced and persistent down-turns as a consequence of the supply chain crisis. The benchmark economy takes long to recover. Moreover the response in wages and inventories is more

Figure 12: Counterfactual: Response of Stock-outs, Gini, and Markups



than twice as strong. Figure 12 shows that qualitatively without risk, stock-out rates and markups fall. Hence, a major contribution to the differential response in wages is the fall in inventories.

Compare to Flexible Pricing. From Figure 11, recovery with flexible pricing is slower than the risk-neutral benchmark, however inflexible pricing slows recovery of outcomes significantly. On impact, wages fall similarly in the flexible pricing model and benchmark, suggesting similar movements in markups. This is confirmed in the final panel of 12. While the expected price is always with a markup of $\frac{\sigma}{\sigma-1}$, the standard CES value, the wedge in the firm-level labor share ex-post leads to a time-varying wedge in labor income, which one can label as the aggregate markup.¹⁵

6 Conclusion

This paper introduces a model of precautionary pricing in which firms facing uninsurable, idiosyncratic demand risk set prices and inventories prior to the realization of demand. Risk aversion induces firms to price as a form of insurance against the risk of stock-outs and surplus inventories. As a result, the model generates dispersion in prices and markups even under constant demand elasticity, and links markup variation to firms' financial positions and exposure to demand volatility.

Quantitatively, the model accounts for key cross-sectional moments in U.S. firm-level data, including the relationship between volatility, inventory investment, and markup dispersion. The empirical evidence confirms that firms with greater idiosyncratic risk, especially

¹⁵This is akin to the aggregate wedge due to labor in Boar et al. (2022) or Di Tella et al. (2025).

those with exposed executives, invest less in inventories as predicted by precautionary motives.

The analysis highlights that idiosyncratic risk and incomplete insurance can generate significant misallocation and amplify macroeconomic fluctuations. During supply-chain disruptions, increased uncertainty about inventory availability raises markups and prolongs recovery relative to an economy with risk-neutral firms.

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A Derivations