

# Endogenous Firm Entry and the Supply-Side Effects of Monetary Policy\*

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## Abstract

We present a model of business cycles with endogenous firm entry. In our framework, short-term supply shifts driven by new firm entries become a crucial factor in driving the economy's response to shocks, regardless of whether those shocks originate from the 'supply' or 'demand' blocks. Specifically, an uptick in aggregate demand triggers a cycle of increased firm entry, thereby enhancing aggregate supply and, in turn, further boosting demand through greater purchases of equipment by new entrants. Monetary policy becomes especially powerful, as it simultaneously impacts aggregate demand and the entry decisions of financially constrained firms. This effect is particularly noticeable in economies with a significant potential for new firm entries. Our analytical approach characterizes equilibrium firm entry as a function of the "policy room", a *sufficient statistic* related to the effectiveness of monetary policy interventions in both the model and the data.

**Keywords:** Monetary Policy, Policy Room, Endogenous Firm Entry

**JEL Codes:** D25, E32, E52

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# 1 Introduction

Contemporary macroeconomic models frequently classify individual shocks into separate “demand” and “supply” blocks.<sup>1</sup> However, distinguishing between them proves challenging in practice, as shocks often appear to intermingle and co-occur, as observed during the recent Covid-19 crisis. In this paper, we operationalize the concept of demand and supply separability (or lack thereof) in a precise manner, employing modern macroeconomic tools within a New Keynesian framework with endogenous firm entry and exit, and in particular study the supply-side effect of monetary policy.

Figure 1 illustrates our basic problem via the classic aggregate demand (AD) and aggregate supply (AS) diagram. In the context of endogenous firm entry, a positive demand shock ( $AD_0$  to  $AD_1$ ) encourages additional supply via firm entry, as firms find it more profitable to enter the market. Consequently, the aggregate supply curve shifts from  $AS_0$  to  $AS_1$ . As new entrants purchase the necessary equipment to operate in the market, this shift in supply further amplifies aggregate demand ( $AD_1$  to  $AD_2$ ), initiating a self-reinforcing cycle between the two. Thus, firm entry generates the following three features: (i) a higher participation rate of firms mitigate the inflationary pressure and raise the output; (ii) demand and supply can be generally intertwined rather than separate, and shocks traditionally attributed to distinct demand-supply blocks have the potential to induce observationally similar co-movements in output and price; (iii) finally, the potency of monetary policy transmission on output will be stronger if endogenous responses in firm entry, thereby shifts in aggregate supply, are bigger.

In this context, the absence of demand-supply separability stems from the simultaneous co-movement of supply and demand, attributed to endogenous firm entry. This differs from the conventional equilibrium, which implies movement *along* the aggregate supply curve, rather than a shift of the curve itself when the economy faces demand shocks. To illustrate the importance of endogenous firm entry in explaining the business cycle, we offer a detailed analytical breakdown of labor adjustments in response to economic shocks, focusing on two key aspects: the extensive margin, which involves hiring by new entrants, and the intensive margin, which involves hiring by existing firms. Our analysis demonstrates that adjustments on the extensive margin are quantitatively significant in driving the economy’s

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<sup>1</sup>In a traditional macroeconomic framework, positive supply shocks (such as technology advancements or decreased cost-push factors) expand the supply curve and lead to lower equilibrium prices and increased production (as captured by the New Keynesian Phillips curve), while demand shocks generate a positive correlation between prices and production.

responses to various economic shocks.

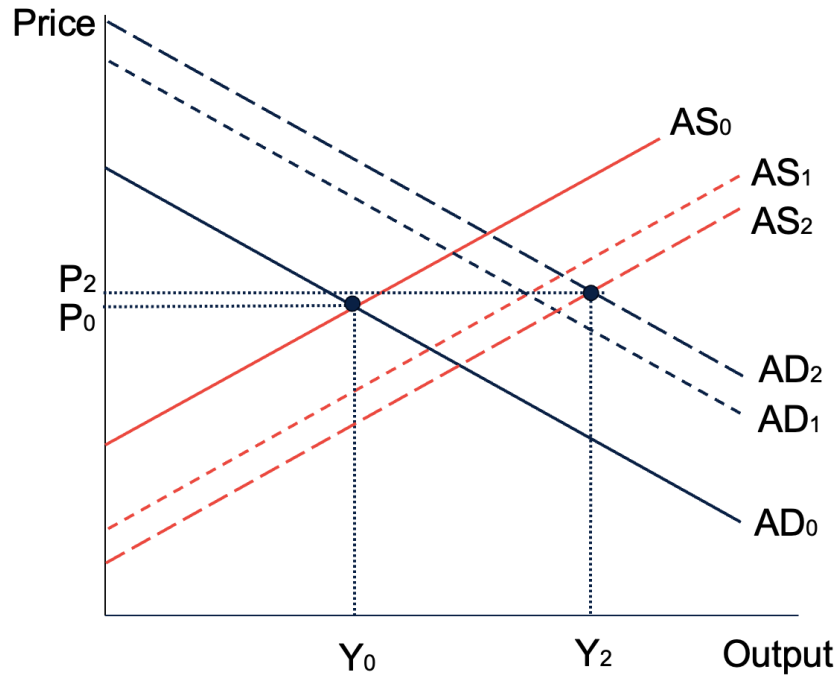


Figure 1: Convoluted aggregate demand and supply with endogenous firm entry

To facilitate the analysis, we decouple endogenous firm entry from other elements of the standard New Keynesian model by separating the production process across downstream and upstream industries. At the downstream level, a fixed measure of identical but differentiated firms engage in the production of a continuum of consumption varieties, face nominal pricing rigidities, and rely on upstream industry inputs. Upstream firms, conversely, enjoy price flexibility and employ labor, feature heterogeneous productivity endowments, and are obligated to incur stochastic fixed costs to enter the market and remain operational in subsequent periods. To further simplify the problem and obtain intuitive analytical expressions, we follow the literature on endogenous entry and assume that productivity and entry costs are drawn from independent Pareto distributions.<sup>2</sup> Finally, we impose a cash-in-advance constraint that, coupled with entry costs, generates upstream industry's reliance on borrowing from capital markets, connecting entry decisions to monetary policy via loan rates.<sup>3</sup> Therefore, monetary accommodation has dual roles: it raises aggregate demand as well as

<sup>2</sup>For the use of Pareto distributions for tractability purposes, see e.g., Melitz (2003).

<sup>3</sup>Therefore, given a fixed cost level, a lower policy rate raises the likelihood that a firm operates in the market in the subsequent period.

encourages additional firm entries by reducing the loan rates faced by firms, triggering a self-reinforcing cycle between demand and supply.

While stylized, our model yields several interesting analytical outcomes, one of which is the formulation of a minimum policy rate, termed the “Satiation Bound (SB)”, which is defined as the threshold rate that ensures full market participation of firms with comparable fixed costs. When the policy rate falls below SB, firms with even the lowest productivity will find market entry profitable. As a result,<sup>4</sup> market participation becomes less responsive to further monetary policy easing and other expansionary economic shocks. In such scenarios, the horizontal shift of the aggregate supply (AS) curve depicted in Figure 1 gradually diminishes as the policy rate falls. Consequently, the effectiveness of monetary policy in stimulating production diminishes, leading to reduced output multipliers and more pronounced inflationary responses, among others.

This observation suggests that the gap between the current policy rate and the average Satiation Bound (SB), which we refer to as the “policy room”, acts as a *sufficient statistic* for gauging the supply-side impact of monetary policy. In fact, our model generates significant correlation between our “policy room” measure and the potency of monetary policy, as well as general responses to other shocks.

Finally, we empirically recover a measure of the policy room for the US economy and test the key model implication that the potency of monetary policy is strengthened as the policy room widens. Our empirical findings support the existence of such a mechanism in the data, indicating that a two percent wider policy room decreases output by up to an additional three percentage points in response to a one standard deviation (29 basis points) monetary tightening shock.

**Related literature** Our business cycle setting with endogenous (upstream) firm entry follows previous works in the literature, e.g., Bilbiie et al. (2007), Bergin and Corsetti (2008),<sup>5</sup> Stebunovs (2008), Kobayashi (2011) Bilbiie et al. (2012), Uusküla (2016), Hamano and Zanetti (2017). While some papers assume equity financing for newly entering firms, e.g., Bilbiie et al. (2007), Bergin and Corsetti (2008), Bilbiie et al. (2012),<sup>6</sup> new firms finance

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<sup>4</sup>As firms with the lowest productivity have already entered the market, additional easing of policy rates does not trigger a new wave of firm entry.

<sup>5</sup>Our assumption that fixed costs for market entry are paid in units of the final consumption goods aligns with the framework proposed by Bergin and Corsetti (2008). However, we deviate from their assumption of “pre-set” output procurement prices in favor of market prices.

<sup>6</sup>Under the equity financing for new entrants, an expansionary monetary shock leads to an increase in the aggregate demand for products, raising labor demand and wages. Higher labor costs for potential entrants

their entry costs via borrowing from a loan market in our model, as in [Stebunovs \(2008\)](#), [Kobayashi \(2011\)](#), [Uusküla \(2016\)](#), so that firm entry is boosted under monetary accommodation, which aligns with the evidence presented in [Colciago and Silvestrini \(2022\)](#).<sup>7</sup> In addition, we express the equilibrium firm entry as a sole function of the “policy room”, a sufficient statistic we devise. Up to our knowledge, we are one of the first works that devise the *sufficient statistic* that accounts for the supply effect of demand shocks and empirically test the channel.<sup>8</sup>

Our characterization of the Satiation Bound (SB) hinges on the idea that (i) monetary expansion facilitates an upswing in firm entry, and (ii) upon the monetary policy rate reaching a specified lower bound, all potential firms associated with a particular fixed entry cost have ventured into the market. Beyond this juncture, the positive supply effects stemming from further monetary accommodation and subsequent firm entry begin to wane. This phenomenon resonates with the insights of [Ulate \(2021\)](#) and [Abadi et al. \(2022\)](#), who incorporate analogous concepts in the context of banking profitability and the negative interest rates.

**Layout** Section 2 presents our New Keynesian model with endogenous firm entry. Section 3 discusses our calibration, steady-state analysis, and comparative statics. The model economy’s impulse response functions to various shocks are explored in Section 4. Section 5 provides our empirical analysis and confirms the model predictions in the data. Concluding remarks are presented in Section 6.

Derivations and proofs are detailed in Appendix A. Appendix B summarizes the equilibrium conditions, inclusive of the flexible-price and steady-state benchmarks. Appendix C provides estimation techniques of the unobservable policy room and the satiation measure based on available data. For supplementary tables and figures, readers are directed to Appendix D. Appendix E presents various robustness checks to our empirical analysis, and lastly, Appendix F provides the derivation of the model under a simplified framework with homogeneous entry costs.

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can lower their net present value and reduce the entry rate of new firms, which is counterfactual. For the role of “real wage rigidity” in resolving this problem, see e.g., [Lewis and Poilly \(2012\)](#).

<sup>7</sup>[Colciago and Silvestrini \(2022\)](#) find the empirical evidence that expansionary monetary policy leads to an initial decrease and then an overshooting in the average productivity of the economy, as well as an initial increase and then undershooting in the firm’s entry rate.

<sup>8</sup>[Bergin and Corsetti \(2008\)](#) similarly find that monetary policy has a significant impact on the creation of new firms. [Jordà et al. \(2024\)](#) find long-run effects of monetary policy, through supply channels including capital stocks and the total factor productivity (TFP), while we focus on short-run supply effects of monetary policy.

## 2 Model

### 2.1 Representative Household

The representative household maximizes lifetime utility given by

$$\max E_t \sum_{j=0}^{\infty} \beta^j \left[ \phi_{c,t} \cdot \log(C_t) - \left( \frac{\eta}{\eta+1} \right) \cdot N_t^{\left( \frac{\eta+1}{\eta} \right)} \right],$$

where  $C_t$  is consumption,  $N_t$  is labor, and  $\phi_{c,t} \equiv \exp(u_{c,t})$  is an aggregate demand shock defined as  $u_{c,t} = \rho_c \cdot u_{c,t-1} + \varepsilon_{c,t}$ ,  $\varepsilon_{c,t} \sim N(0, \sigma_c^2)$ . The household's budget constraint is

$$C_t + \frac{D_t}{P_t} + \frac{B_t}{P_t} = \frac{R_t^D D_{t-1}}{P_t} + \frac{R_t^B B_{t-1}}{P_t} + \frac{W_t N_t}{P_t} + \frac{\Upsilon_t}{P_t},$$

where  $D_t$  represents bank deposits, and  $B_t$  denotes government bonds, which are in zero net supply in equilibrium. The corresponding gross interest rates for these assets are represented by  $R_t^D$  and  $R_t^B$ , respectively.<sup>9</sup>  $\Upsilon_t$  captures lump-sum transfers to households. Such transfers may originate from various sources, including fiscal policies (such as subsidies to firms) or residual firm profits.

The first-order conditions bring the following standard intertemporal and intratemporal equations: The first-order conditions of this problem are

$$\frac{1}{R_t^D} = \frac{1}{R_t^B} = \beta E_t \left[ \frac{\phi_{c,t+1}}{\phi_{c,t}} \cdot \frac{C_t}{C_{t+1} \Pi_{t+1}} \right], \quad (1)$$

$$N_t^{\frac{1}{\eta}} = \phi_{c,t} \cdot C_t^{-1} \cdot \frac{W_t}{P_t}. \quad (2)$$

The household is indifferent between investing in bonds or deposits in equilibrium, and central bank policy via  $R_t^B$  has a one-to-one pass-through on  $R_t^D$ .

### 2.2 Firms

The model stratifies firms into two discrete categories: those belonging to the downstream industry and those in the upstream industry. In both layers, firms operate in an environment of monopolistic competition. Notably, only downstream firms encounter nominal

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<sup>9</sup>We do not consider issues pertaining to the zero lower bound (ZLB) in this paper, so it is possible for interest rates to be negative,  $R_t^D < 1$ .

price rigidities à la [Calvo \(1983\)](#). Operational dynamics are structured such that upstream firms employ labor to generate intermediate input varieties, whose aggregator the downstream firms subsequently incorporate into the production of consumption good varieties. Representative households own firms across both industries, and consume the aggregated downstream goods.

One of the defining elements of our framework is the decision-making process for upstream firms. At each period, firms evaluate whether to continue/start operations in the next period. Should they decide to remain/enter the market, they must incur certain fixed costs, denominated in final goods, which are financed through loans from the banking sector.<sup>10</sup>

### 2.2.1 Downstream Industry: Aggregator

A representative firm, operating under perfect competition, aggregates the differentiated products produced by a continuum of downstream firms, denoted by  $u$ , spanning the interval  $[0, 1]$ . This can be formally expressed as:

$$Y_t = \left[ \int_0^1 Y_t(u)^{\frac{\gamma-1}{\gamma}} du \right]^{\frac{\gamma}{\gamma-1}} .$$

The demand for each distinct variety produced by downstream firms, as well as the aggregate price, are given by

$$\begin{aligned} Y_t(u) &= \left( \frac{P_t(u)}{P_t} \right)^{-\gamma} Y_t , \\ P_t &= \left[ \int_0^1 P_t(u)^{1-\gamma} du \right]^{\frac{1}{1-\gamma}} , \end{aligned} \tag{3}$$

where  $Y_t(u)$  and  $P_t(u)$  are the output and prices of downstream varieties, respectively. Let  $X_t = P_t Y_t$  represent the nominal aggregate expenditure, and  $X_t(u) = P_t(u) Y_t(u)$  denote the expenditure for a specific downstream variety  $u$ . Given these definitions, the individual demands can be reformulated as:

$$X_t(u) = \Gamma_t \cdot P_t(u)^{1-\gamma} , \quad \text{where: } \Gamma_t = X_t P_t^{\gamma-1} .$$

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<sup>10</sup>This dependency on external funding effectively functions as a cash-in-advance production constraint.

### 2.2.2 Downstream Industry: Monopolistic Competition with Sticky Prices

Consider a firm  $u$  within the downstream industry, belonging to the interval  $[0, 1]$ . This firm employs  $J_t(u)$  units of the aggregate product from the upstream industry and produces  $Y_t(u) = J_t(u)$ , indicating a one-to-one transformation from input to output. Consequently, the aggregate sum of upstream products, denoted as  $J_t$ , satisfies:  $J_t \equiv \int_0^1 J_t(u) \, du = \int_0^1 Y_t(u) \, du$ .

The profit equation for a downstream firm  $u$  is given by

$$\Pi_t(u) = (1 + \zeta^T)P_t(u)Y_t(u) - P_t^J J_t(u) ,$$

where  $P_t^J$  represents the price of the aggregate upstream product, and  $\zeta^T$  stands for a production subsidy to downstream firms. Thus, the present discounted value of profits, which the downstream firm  $u$  seeks to maximize, can be expressed as:

$$\sum_{l=0}^{\infty} E_t \{ Q_{t,t+l} [(1 + \zeta^T)P_{t+l}(u)Y_{t+l}(u) - P_{t+l}^J J_{t+l}(u)] \} ,$$

with  $Q_{t,t+l}$  being the stochastic discount factor between time  $t$  and  $t + l$ .

Firms in the downstream industry face price stickiness à la [Calvo \(1983\)](#), characterized by a price-resetting probability of  $1 - \theta$ . A firm, when adjusting its price  $P_t^*$ , aims to:

$$\max_{P_t^*} \sum_{l=0}^{\infty} E_t \left\{ Q_{t,t+l} \theta^l [(1 + \zeta^T)P_t^* - P_{t+l}^J] \left( \frac{P_t^*}{P_{t+l}} \right)^{-\gamma} Y_{t+l} \right\} ,$$

where all firms that adjust their prices select  $P_t^*$  as the revised price. The resulting first-order condition can be articulated as:

$$\frac{P_t^*}{P_t} = \frac{\sum_{l=0}^{\infty} E_t \left\{ Q_{t,t+l} \theta^l \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right) \left( \frac{P_{t+l}}{P_t} \right)^{\gamma+1} \left( \frac{P_{t+l}^J}{P_{t+l}} \right) Y_{t+l} \right\}}{\sum_{l=0}^{\infty} E_t \left\{ Q_{t,t+l} \theta^l \left( \frac{P_{t+l}}{P_t} \right)^{\gamma} Y_{t+l} \right\}} . \quad (4)$$

### 2.2.3 Upstream Industry: Aggregator

There exists a continuum of upstream firms spanning the interval  $[0, 1]$ , each producing a distinct variety. These firms exhibit heterogeneity in two principal dimensions: productivity, indexed by  $v$ , and operational fixed costs, indexed by  $m$ . The output of a firm, uniquely



identified by the index pair  $mv$ , is defined as  $J_{mv,t}$ . A perfectly competitive firm aggregates these upstream varieties as:

$$J_t = \left[ \int_0^1 \int_{v \in \Omega_{m,t}} J_{mv,t}^{\frac{\sigma-1}{\sigma}} dv dm \right]^{\frac{\sigma}{\sigma-1}},$$

where  $\Omega_{m,t}$  denotes the subset of upstream firms sharing the same operational fixed cost  $m$  that decide to produce in period  $t$ . Given significant fixed costs, only the firms with the highest productivity levels may find production viable. The demand for an individual upstream variety  $(m, v)$ , is:

$$J_{mv,t} = \left( \frac{P_{mv,t}^J}{P_t^J} \right)^{-\sigma} J_t. \quad (5)$$

Subsequently, the aggregate price index for the upstream product is:

$$P_t^J = \left[ \int_0^1 \underbrace{\int_{v \in \Omega_{m,t}} (P_{mv,t}^J)^{1-\sigma} dv}_{\equiv (P_{m,t})^{1-\sigma}} dm \right]^{\frac{1}{1-\sigma}} = \left[ \int_0^1 (P_{m,t}^J)^{1-\sigma} dm \right]^{\frac{1}{1-\sigma}}, \quad (6)$$

where  $P_{m,t}^J$  serves as the aggregate price of input for firms bearing the fixed costs indexed by  $m$ . We further define the nominal expenditure on a given upstream variety as  $X_{mv,t}^J = P_{mv,t}^J J_{mv,t}$ , and the aggregate expenditure as  $X_t^J = P_t^J J_t$ , so

$$X_{mv,t}^J = \Gamma_t^J \cdot P_{mv,t}^{1-\sigma}, \quad \text{where: } \Gamma_t^J = X_t^J (P_t^J)^{\sigma-1}. \quad (7)$$

Using equation (3), we can express the aggregate input demand of downstream firms as:

$$J_t = \int_0^1 Y_t(u) du = Y_t \underbrace{\int_0^1 \left( \frac{P_t(u)}{P_t} \right)^{-\gamma} du}_{\equiv \Delta_t} = Y_t \Delta_t, \quad (8)$$

where

$$\Delta_t = (1 - \theta) \left( \frac{P_t^*}{P_t} \right)^{-\gamma} + \theta \Pi_t^\gamma \Delta_{t-1}, \quad (9)$$

represents a measure of price dispersion. Utilizing equation (8), equation (7) can be expressed as  $\Gamma_t^J = (P_t^J)^\sigma Y_t \Delta_t$ .

## 2.2.4 Upstream Industry: Monopolistic Competition, Loans, and Entry Decisions

The production function for an arbitrary firm  $(m, v)$  features diminishing returns to scale and is given by

$$J_{mv,t} = \varphi_{mv,t} \cdot N_{mv,t}^\alpha, \quad \text{with } 0 < \alpha \leq 1,$$

where  $N_{mv,t}$  denotes the labor employed, and  $\varphi_{mv,t}$  is a firm-specific productivity assumed to be drawn from a Pareto distribution,  $\varphi_{mv,t} \stackrel{\text{iid}}{\sim} \mathcal{P}\left(\left(\frac{\kappa-1}{\kappa}\right) A_t, \kappa\right)$ , with  $A_t$  being the average aggregate productivity. A higher  $\kappa$  implies that the productivity distribution is more concentrated around its mean,  $A_t$ . The cumulative distribution function is given by:

$$\Psi(\varphi_{mv,t}) = 1 - \left( \frac{\left(\frac{\kappa-1}{\kappa}\right) A_t}{\varphi_{mv,t}} \right)^\kappa,$$

with the probability distribution function defined as  $\psi(\varphi_{mv,t}) \equiv \Psi'(\varphi_{mv,t})$ .

**Profit Function:** Firms must pay a pre-determined in-kind fixed cost,  $F_{m,t-1}$ , in the preceding period (i.e., at  $t-1$ ) to operate in each period  $t$ . This cost, which covers expenses such as equipment acquisition, is assumed to be financed through loans financed at the prevailing gross rate,  $R_{t-1}^J$ . The profit for an upstream firm, if it chooses to operate in period  $t$ , is:

$$\Pi_{mv,t}^J = \underbrace{(1 + \zeta^J) P_{mv,t}^J J_{mv,t}}_{\equiv r_{mv,t}} - W_t N_{mv,t} - R_{t-1}^J P_{t-1} F_{m,t-1}, \quad (10)$$

where  $\zeta^J$  is a production subsidy to upstream firms and  $r_{mv,t}$  represents their revenue. These upstream firms operate in a monopolistically competitive market and are not subject to nominal rigidities, setting prices as a constant markup over marginal costs (if they decide to produce), formally:

$$P_{mv,t}^J = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right) W_t \varphi_{mv,t}^{-\frac{1}{\alpha}} J_{mv,t}^{\frac{1-\alpha}{\alpha}}. \quad (11)$$

By substituting the derived price equation into equation (10) and using the demand equations (5) and (7), we can rewrite the profit function as:

$$\Pi_{mv,t}^J = \Xi_t \cdot \varphi_{mv,t}^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} - R_{t-1}^J P_{t-1} F_{m,t-1}, \quad (12)$$

where

$$\Xi_t \equiv \frac{\alpha + \sigma(1 - \alpha)}{(\sigma - 1)\alpha} \left( \frac{(1 + \zeta^J)^{-1}\sigma}{(\sigma - 1)\alpha} \right)^{\frac{-\sigma}{\alpha + \sigma(1 - \alpha)}} W_t^{\frac{\alpha(1 - \sigma)}{\alpha + \sigma(1 - \alpha)}} (\Gamma_t^J)^{\frac{1}{\alpha + \sigma(1 - \alpha)}} . \quad (13)$$

**Entry Decision:** Firms' entry decision is taken one-period ahead in  $t - 1$ , and is based on their expected profits and associated costs in  $t$ . We assume that firms know at  $t - 1$  their forthcoming productivity for period  $t$ ,  $\varphi_{mv,t}$ . However, they remain uninformed about other eventual shocks that could impact individual demand in  $t$ .<sup>11</sup> Should a firm decide to operate, it will subsequently hire labor in  $t$  from the spot market, realizing profits as described in equation (12). Given the productivity draws, we can pinpoint the productivity threshold,  $\varphi_{m,t}^*$ , below which a firm would expect zero profit. Firms with the same fixed cost,  $F_{m,t-1}$ , and their productivity draw below this threshold will opt out of market entry for period  $t$ . Using equation (12), the formal representation of  $\varphi_{m,t}^*$  is:

$$E_{t-1} [\xi_t \cdot \Xi_t] \cdot (\varphi_{m,t}^*)^{\frac{\sigma-1}{\alpha + \sigma(1 - \alpha)}} - R_{t-1}^J P_{t-1} F_{m,t-1} = 0 , \quad \text{where: } \xi_t = \frac{Q_{t-1,t}}{E_{t-1} [Q_{t-1,t}]} . \quad (14)$$

It's important to note that this threshold,  $\varphi_{m,t}^*$ , is based on *ex-ante* expected profits. Once a firm  $(m, v)$  commits to market entry, unforeseen shocks could potentially push profits into negative figures. Considering the inherent lower limit on productivity,  $(\frac{\kappa-1}{\kappa}) A_t$ , the actual productivity threshold for entry becomes  $\max \{ \varphi_{m,t}^*, (\frac{\kappa-1}{\kappa}) A_t \}$ .<sup>12</sup> The proportion of firms with a fixed cost  $F_{m,t-1}$  that decide to operate in  $t$  is denoted as  $M_{m,t}$  and is given by

$$M_{m,t} \equiv Prob(\varphi_{mv,t} \geq \varphi_{m,t}^*) = \min \left\{ \left( \frac{E_{t-1} [\xi_t \cdot \Xi_t] \left[ (\frac{\kappa-1}{\kappa}) A_t \right]^{\frac{\sigma-1}{\alpha + \sigma(1 - \alpha)}}}{R_{t-1}^J P_{t-1} F_{m,t-1}} \right)^{\frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\sigma-1}}, 1 \right\} , \quad (15)$$

where we use (14) to substitute for  $\varphi_{m,t}^*$  in the last expression. From this equation, we can derive the following proposition:

**Proposition 1** *For upstream firms with a fixed cost of  $F_{m,t-1}$ ,  $\underline{M_{m,t}} = 1$  when the policy*

<sup>11</sup>This contrasts with Burnside et al. (1993), where labor decisions precede the realization of shocks. In our model, the decision to enter the market precedes the realization of other demand shocks. For simplicity, we assume that firms possess perfect foresight regarding their next period's productivity.

<sup>12</sup>If  $\varphi_{m,t}^*$  is below  $(\frac{\kappa-1}{\kappa}) A_t$ , then all firms categorized by fixed cost  $m$  will operate in  $t$ .

rate  $R_{t-1}^J$  is below a threshold  $R_{m,t-1}^{J,*}$  given by

$$R_{m,t-1}^{J,*} \equiv \frac{E_{t-1} [\xi_t \cdot \Xi_t] \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}}{P_{t-1} F_{m,t-1}}. \quad (16)$$

We refer to this threshold,  $R_{m,t-1}^{J,*}$ , as the “satiation bound” (SB) for firms of fixed cost type  $m$ .

As the policy rate,  $R_{t-1}^J$ , falls, more firms with the fixed cost  $F_{m,t-1}$  opt for market entry in  $t$  due to the reduced loan repayment costs. Upon the policy rate reaching the type-specific bound  $R_{m,t-1}^{J,*}$ , all firms sharing the fixed cost  $F_{m,t-1}$  (or lower) decide to become operational in  $t$ , leading to a stagnation in market entry for firms of cost type  $m$  and below. This fixed cost type-specific lower bound on the policy rate,  $R_{m,t-1}^{J,*}$ , is hence termed the satiation bound (SB).

In addition to the conventional intertemporal substitution effect captured by the Euler equation (1), monetary policy wields influence over the market entry decisions of upstream firms. This, in turn, impacts the input market’s prices and quantities, cascading onto the aggregate economy via downstream product markets. Upon the rate hitting the SB for firms with the fixed cost  $F_{m,t-1}$ , no supplementary entries occur, rendering the supply-side effect of monetary policy ineffectual for such firms.

**Loan Demand:** From equation (15), we derive the expression for the aggregate real loan demand of firms with a fixed cost type  $m$ :

$$\frac{L_{m,t-1}}{P_{t-1}} = M_{m,t} \cdot F_{m,t-1}. \quad (17)$$

Firms opting to operate in period  $t$  borrow an amount  $L_{m,t-1}$  to acquire final goods equivalent to  $F_{m,t-1}$ . This acquisition of final goods connects the entry decisions of firms to the aggregate demand of the economy via the loan channel.

**Fixed Cost Distribution:** We assume that the fixed costs of upstream firms,  $F_{m,t}$ , are drawn from a Pareto distribution,  $F_{m,t} \stackrel{\text{iid}}{\sim} \mathcal{P} \left( \left( \frac{\omega-1}{\omega} \right) F_t, \omega \right)$ , where  $F_t$  represents the average fixed cost associated with running a business, and  $\omega > 1$  is the parameter that determines

the variance of the distribution. The associated cumulative distribution function is:

$$H(F_{m,t}) = 1 - \left( \frac{\left(\frac{\omega-1}{\omega}\right) F_t}{F_{m,t}} \right)^\omega, \quad (18)$$

and its probability distribution function is denoted by  $h(F_{m,t}) \equiv H'(F_{m,t})$ . From Proposition 1, we obtain the probability measure of fixed cost types  $F_{m,t-1}$  that are fully satiated, that is, the share of all firms with fixed cost  $F_{m,t-1}$  that have already entered the market by time  $t$ , thus resulting in  $M_{m,t} = 1$ . This leads us to the following proposition:

**Proposition 2** *Given the distribution in equation (18), the probability that  $M_{m,t} = 1$  is:*

$$Pr \left( R_{t-1}^J \leq R_{m,t-1}^{J*} \right) = Pr \left( F_{m,t-1} \leq \underbrace{\frac{E_{t-1} [\xi_t \cdot \Xi_t] \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}}{R_{t-1}^J P_{t-1}}}_{\equiv F_{t-1}^*} \right) \equiv H \left( F_{t-1}^* \right),$$

where  $F_{t-1}^*$  is the fixed cost threshold as defined above. All firms with a fixed cost  $F_{m,t-1}$  less than or equal to  $F_{t-1}^*$ , irrespective of their productivity values  $\varphi_{mv,t}$ , opt to produce in period  $t$ . We term  $F_{t-1}^*$  the “full satiation fixed cost threshold”.

Proposition 2 can be interpreted as follows: If a firm’s fixed cost,  $F_{m,t-1}$ , is sufficiently low —below the threshold  $F_{t-1}^*$ — then even a firm with the lowest productivity draw would still deem operations in period  $t$  as profitable. Consequently, all firms bearing that fixed cost, regardless of their respective productivity draws, are active in period  $t$ .

**Upstream Industry: Aggregation:** The price aggregator for operating upstream firms, denoted by  $P_t^J$ , can be expressed as:

$$\frac{P_t^J}{P_t} = \left( \frac{W_t}{P_t A_t} \right) \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1-\alpha}{\alpha}} \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H \left( F_{t-1}^* \right)} \right]^{\left( \frac{\alpha+\sigma(1-\alpha)}{\alpha(\sigma-1)} \right)}, \quad (19)$$

where  $\Theta_3 = \frac{\kappa[\alpha+\sigma(1-\alpha)]+(\omega-1)(\sigma-1)}{\Theta_1 \omega(\sigma-1)}$  and  $\Theta_4 = \frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\omega(\sigma-1)}$  are constants. The aggregate measure of firms that operate during period  $t$ , represented by  $M_t$ , is given by

$$M_t = \int_0^1 \int_{v \in \Omega_{m,t}} 1 \, dv \, dm = 1 - \Theta_M \cdot [1 - H \left( F_{t-1}^* \right)], \quad (20)$$

where  $\Theta_M = \frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)]+\omega(\sigma-1)}$ . Subsequently, the aggregate loan demand from operational upstream firms can be derived as:

$$\frac{L_{t-1}}{P_{t-1}} = \frac{1}{P_{t-1}} \int_0^1 L_{m,t-1} dm = F_{t-1} \cdot \left[ 1 - \Theta_L \cdot [1 - H(F_{t-1}^*)]^{\left(\frac{\omega-1}{\omega}\right)} \right], \quad (21)$$

where  $\Theta_L = \frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)]+(\sigma-1)(\omega-1)}$  is another model constant.

In equation (20), notice that as the satiation measure  $H(F_{t-1}^*)$  increases, the number of operational firms at time  $t$  also increases. From equation (21), the aggregate real loan demand of firms is proportional to the average fixed cost,  $F_{t-1}$ , and grows with the satiation rate  $H(F_{t-1}^*)$ . Finally, in equation (19), the relative price of inputs from upstream firms relates to the technology-adjusted real wage,  $\frac{W_t}{P_t A_t}$ , and the aggregate demand for inputs of downstream firms,  $\frac{Y_t \Delta_t}{A_t}$ . When participation from upstream firms increases, as indicated by  $H(F_{t-1}^*)$ , this relative price decreases. This is due to more upstream varieties being available to downstream firms, leading to greater competition and lower input prices. Therefore, the entry of new firms can reduce marginal costs for downstream firms and mitigate inflationary pressures.

**Average SB:** We obtain the average satiation interest rate of the economy by integrating over equation (16), and denote it by  $R_{t-1}^{J,*}$ . This rate serves as a measure of the satiation propensity of upstream firms. When the prevailing policy rate  $R_{t-1}^J$  exceeds this average, a marginal reduction in  $R_{t-1}^J$  can induce an entry of upstream firms into the market. According to equation (19), this market entry can lower average input prices and subsequently mitigate inflation. It can also boost aggregate demand and increase the price level, as new entrants take out loans to meet fixed costs, thus enabling the acquisition of fixed equipment for the production of final goods.

**Proposition 3** *The aggregate satiation bound (SB) is expressed as:*

$$R_{t-1}^{J,*} = \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{\infty} R_{m,t-1}^{J,*} dH(F_{m,t-1}) = \left( \frac{\omega^2}{\omega^2 - 1} \right) \cdot \frac{F_{t-1}^*}{F_{t-1}} \cdot R_{t-1}^J, \quad (22)$$

where  $F_{t-1}^*$  is the threshold fixed cost relative to the average fixed cost  $F_{t-1}$  in the economy.

If the threshold fixed cost for satiation,  $F_{t-1}^*$ , surpasses the economy's average fixed cost  $F_{t-1}$ , it signals an elevated likelihood of satiation across diverse fixed cost categories. Consequently, that results in a high value of the average SB rate,  $R_{t-1}^{J,*}$ , relative to the

policy rate,  $R_{t-1}^J$ . In such a situation, a minor ease in  $R_{t-1}^J$  may not substantially stimulate the entry of new upstream firms.

**Limit case,  $\omega \rightarrow \infty$ :** Under our calibration, the fixed cost distribution  $H(F_{m,t})$  collapses to its mean value,  $F_t$ , thereby becoming degenerate. This results in a uniform fixed cost across all firms. The economy's state—whether fully satiated or not—is determined by the relative sizes of the policy rate  $R_{t-1}^J$  and the mean satiation bound,  $R_{t-1}^{J,*}$ . Specifically, if  $R_{t-1}^J < R_{t-1}^{J,*}$ , all upstream firms enter the market and commence production in  $t$ . This simplified version of the model yields analytically tractable equilibrium expressions. Additional insights into the equilibrium conditions for this scenario are provided in Appendix F.

### 2.3 Shock Processes

The average fixed cost  $F_t$  is modeled as follows:

$$F_t = \phi_f \cdot \bar{Y}_t \cdot \exp(u_{f,t}) = \phi_f \cdot \frac{Y}{A} \cdot A_t \cdot \exp(u_{f,t}), \quad (23)$$

where  $u_{f,t} = \rho_f \cdot u_{f,t-1} + \varepsilon_{f,t}$  and  $\varepsilon_{f,t}$  is normally distributed with mean 0 and variance  $\sigma_f^2$ . Here,  $\frac{Y}{A}$  is the steady-state output level adjusted for technology, and  $\bar{Y}_t = \frac{Y}{A} \cdot A_t$  represents the balanced-growth path output.<sup>13</sup>

For technological progress, the model adopts:

$$GA_t \equiv \frac{A_{t+1}}{A_t} = (1 + \mu) \cdot \exp\{u_{a,t}\},$$

where  $u_{a,t} = \rho_a \cdot u_{a,t-1} + \varepsilon_{a,t}$ , and  $\varepsilon_{a,t}$  is normally distributed with mean 0 and variance  $\sigma_a^2$ .

Additionally, government expenditure  $G_t$  is formulated as:

$$G_t = \phi_g \cdot Y_t \cdot \exp(u_{g,t}), \quad (24)$$

where  $u_{g,t} = \rho_g \cdot u_{g,t-1} + \varepsilon_{g,t}$ , and  $\varepsilon_{g,t}$  is normally distributed with mean 0 and variance  $\sigma_g^2$ . It is assumed that the government maintains fiscal balance, levying a lump-sum tax, i.e.,  $T_{g,t} = G_t$  on the representative household each period.<sup>14</sup>

<sup>13</sup>We assume that  $F_t$  scales with balanced-growth-path output  $\bar{Y}_t$ , not the contemporaneous output  $Y_t$ . In practice, this assumption has minimal quantitative impact.

<sup>14</sup>Considering a zero net supply of government bonds, the government's budget constraint is upheld.

## 2.4 Central Bank

We assume that the central bank follows a Taylor rule for interest rate determination. The formal representation of this rule is given by:

$$R_t^B = R_t^J = R^J \cdot \left( \frac{\Pi_t}{\bar{\Pi}} \right)^{\tau_\pi} \left( \frac{Y_t}{\bar{Y}_t} \right)^{\tau_y} \cdot \exp\{\varepsilon_{r,t}\},$$

where  $\varepsilon_{r,t}$  is a normally distributed idiosyncratic monetary policy shock with mean 0 and variance  $\sigma_r^2$ . The variable  $\bar{Y}_t$  denotes the balanced-growth path output level, and  $\bar{\Pi}$  indicates the steady-state trend inflation rate. Financial markets are competitive, and the rate that households face, i.e.,  $R_t^B$ , equals  $R_t^J$  in equilibrium, the loan rate faced by upstream firms.

## 2.5 Aggregation

Here, we aggregate the equations presented in Section 2.2 to obtain the economy-wide conditions. Consider first the aggregate labor demand  $N_t$ , given by

$$N_t = \Theta_N \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \cdot (1 + \Theta_4 H_{t-1})^{-\frac{\alpha + \sigma(1-\alpha)}{(\sigma-1)\alpha}}, \quad (25)$$

where  $H_{t-1} \equiv H(F_{t-1}^*)$  for simplicity, and

$$\begin{aligned} \Theta_N = & \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1-\alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma-1}{\alpha + \sigma(1-\alpha)} \right)} \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)} \right) \\ & \cdot \left( \frac{\omega(\sigma - 1)}{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)} \right) \Theta_3^{\left( \frac{\sigma}{\alpha(\sigma-1)} \right)} > 0. \end{aligned} \quad (26)$$

From equation (25), it becomes evident that aggregate labor demand,  $N_t$ , is positively correlated with the demand for upstream varieties, denoted by  $J_t$ . Conversely, the demand for labor decreases as the satiation measure,  $H_{t-1}$ , rises. An increase in  $H_{t-1}$  results in a higher aggregate measure of operating firms,  $M_t$ , as indicated in equation (20). This increase consequently stimulates employment through new entrants on the extensive margin. However, this surge in market entry also exerts downward pressure on the relative input price,  $\frac{P_t^J}{P_t}$ , and dampens the individual labor demand of existing firms,  $N_{mv,t}$ , due to intensified competition. In practice, the latter effect dominates and the reduction in labor demand at the intensive margin outweighs the increase at the extensive margin induced by new market



entrants, provided that  $J_t$  is held constant.

The real wage, based on the household's intratemporal optimization condition in equation (2) and equation (25), is given by

$$\frac{W_t}{P_t A_t} = \Theta_N^{\frac{1}{\eta}} \left( \frac{C_t}{A_t} \right) \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\eta \alpha}} (1 + \Theta_4 H_{t-1})^{-\frac{\alpha + \sigma(1-\alpha)}{\eta(\sigma-1)\alpha}} \cdot \exp \{-u_{c,t}\} . \quad (27)$$

Substituting equation (27) into equation (19) yields:

$$\frac{P_t^J}{P_t} = \Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\alpha + \sigma(1-\alpha)}{(\sigma-1)\alpha}} \left( \frac{C_t}{A_t} \right) \left( \frac{Y_t \Delta_t}{A_t} \right)^{\left( \frac{(1-\alpha)\eta + 1}{\eta \alpha} \right)} (1 + \Theta_4 H_{t-1})^{-\frac{(1+\eta)[\alpha + \sigma(1-\alpha)]}{\eta(\sigma-1)\alpha}} \cdot \exp \{-u_{c,t}\} . \quad (28)$$

Analysis of equations (25), (27), and (28) confirms that, given fixed aggregate demand measures such as  $C_t$  and  $J_t$ , an increase in  $H_{t-1}$  results in a reduction of both individual and aggregate labor demand. Consequently, this drives down the equilibrium wage. Hence, an increase in the entry of upstream firms exerts a deflationary impact on the economy, signaling a positive shift in aggregate supply.

**Market clearing:** Market clearing in this economy is given by

$$C_t + \frac{L_t}{P_t} + G_t = Y_t , \quad (29)$$

which, in conjunction with equations (21), (23), and (24), can be reformulated as:

$$\frac{C_t}{Y_t} = 1 - \phi_g \cdot \exp \{u_{g,t}\} - \phi_f \cdot \left( \frac{\tilde{Y}_t}{\bar{Y}} \right)^{-1} \cdot \left[ 1 - \Theta_L \cdot [1 - H_t]^{\left( \frac{\omega-1}{\omega} \right)} \right] \cdot \exp \{u_{f,t}\} . \quad (30)$$

Notice that real loan demand is present on the left-hand side of equation (29). When upstream firms opt to operate in the next period, they secure loans from financial institutions and utilize them to pay for in-kind fixed costs in terms of the final consumption good. This raises aggregate demand, exerting an inflationary influence in the economy as shown in equations (27) and (28): in those equations, stronger aggregate demand translates to inflation.<sup>15</sup>

<sup>15</sup>A Keynesian-cross structure becomes evident in equation (29) when endogenous entry of upstream firms is considered. As  $Y_t$  expands, the measure of operating upstream firms,  $M_t$ , along with their loan demand,  $\frac{L_t}{P_t}$ , rises, thus generating successive increments in demand.

Consequently, the entry of upstream firms into the market has the dual effect of shifting both the aggregate supply and demand curves. Depending on the relative magnitudes of these shifts, market entry can exhibit either inflationary or deflationary tendencies. Section 4 will elaborate on the economy’s short-run responses to demand and supply shocks within this framework, underscoring the inherent linkage between the two.

In Guerrieri et al. (2023), a sectoral supply shock —such as the closing of high-contact sectors due to Covid-19— is more likely to become Keynesian, triggering a more substantial shift in aggregate demand than in supply, especially in multi-sector economies with incomplete markets. While their focus is primarily on economies where the sector affected by the supply shock either complements or utilizes inputs from unaffected sectors, our dual-layered structure (comprising downstream and upstream industries) enables an exploration of the reciprocal impacts between supply and demand. Specifically, in our model, a supply shock to upstream firms causes shifts in aggregate demand via the labor market and loan demand. Conversely, a demand shock initiates shifts in the upstream supply curve, affecting downstream supply primarily through their impact on input prices, and thereby resulting in successive rounds of demand shifts.

**Average SB and satiation:** Upon substituting equation (A.24) in Appendix A into (22), we obtain an expression for the average SB rate:

$$R_t^{J,*} = \left( \frac{\omega}{\omega + 1} \right) \cdot (1 - H_t)^{-\frac{1}{\omega}} \cdot R_t^B . \quad (31)$$

This expression allows us to interpret the “policy room”, denoted as  $\frac{R_t^B}{R_t^{J,*}}$ , as a decreasing function of the satiation measure  $H_t$ .

Corollary 1 re-expresses the policy room  $\frac{R_t^B}{R_t^{J,*}}$  as a *sufficient statistic* for the aggregate participation rate of firms,  $M_{t+1}$ . Importantly, a wider policy room level (i.e., higher  $\frac{R_t^B}{R_t^{J,*}}$ ) amplifies the impact of monetary easing on the entry of upstream firms.<sup>16</sup> This rests on the following straightforward logic: a relatively high current policy rate  $R_t^B$  compared to the average SB,  $R_t^{J,*}$ , increases the scope for additional firms to enter the market as the policy

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<sup>16</sup>This is consistent with the concave and decreasing function  $M_{t+1}$  in relation to the policy rate,  $R_t^B$ , as seen in (33).

rate declines.<sup>17</sup> Note from equation (31) above that

$$\frac{R_t^B}{R_t^{J,*}} \leq \frac{\omega + 1}{\omega} . \quad (32)$$

**Corollary 1** *The total measure of upstream firms opting to operate in period  $t + 1$  is:*

$$M_{t+1} = 1 - \Theta_M \cdot \left[ \left( \frac{\omega}{\omega + 1} \right) \cdot \frac{R_t^B}{R_t^{J,*}} \right]^\omega , \quad (33)$$

and a decrease in the policy room  $\frac{R_t^B}{R_t^{J,*}}$  generates a larger increment in  $M_{t+1}$  when starting from a higher initial policy room level.

**Proof.** Directly from equation (33), we find:

$$\frac{dM_{t+1}}{d\left(\frac{R_t^B}{R_t^{J,*}}\right)} = -\omega \Theta_M \left[ \left( \frac{\omega}{\omega + 1} \right) \cdot \frac{R_t^B}{R_t^{J,*}} \right]^{\omega-1} \cdot \frac{\omega}{\omega + 1} < 0 ,$$

whose absolute magnitude is increasing in the level of  $\frac{R_t^B}{R_t^{J,*}}$ , given  $\omega > 1$ . ■

**Flexible Price Model:** Under flexible prices, the price of consumption varieties produced by downstream firms exhibits a constant markup over the cost of upstream inputs. Mathematically, this relationship is expressed as:

$$\frac{P_t}{P_t^J} = \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} . \quad (34)$$

This establishes that the flexible price equilibrium is money-neutral, signifying that the policy rate  $R^J$  exerts no influence on the real allocation of resources. Additional equilibrium conditions are provided in Appendix A.

## 2.6 Summary Equilibrium Conditions

For analytical tractability, balanced growth path-adjusted variables are denoted with a tilde, for example,  $\tilde{Y}_t \equiv \frac{Y_t}{A_t}$ . In our simulation results, we assume the government implements optimal transfers to neutralize real distortions arising from monopolistic competition. Specif-

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<sup>17</sup>This pertains to scenarios where the fixed cost cutoff  $F_t^*$  is low, thus allowing middle-range fixed cost firms with suboptimal productivity to enter the market.

ically, this involves setting  $\zeta^T = \frac{1}{\gamma-1}$  and  $\zeta^J = \frac{1}{\sigma-1}$ . A comprehensive list of equilibrium conditions is provided in Appendix B.

## 3 Steady State Results

### 3.1 Calibration and Estimation

The calibrated parameters are presented in Table 1. Our model incorporates two key factors influencing the operation of upstream firms in the market: fixed costs and productivity. These two variables follow their own independent Pareto distributions. The model is designed such that the proportion of operating upstream firms is sensitive to parameters associated with these Pareto distributions. Utilizing the calibrated parameters outlined in Table 1, our model effectively replicates the moments commonly targeted in the literature. Key steady-state values are displayed in Table 2.

**Fixed Cost to Balanced-Growth-Path Output Ratio,  $\phi_f$ :** In Appendix C, we estimate the parameters  $(\phi_f, \rho_f, \sigma_f)$  of equation (23), based on the available data on the number of establishments in the Quarterly Census of Employment and Wage (QCEW) database as a proxy for firm participation in the model.<sup>18</sup>

The estimated  $\phi_f = 0.5547$ , obtained by matching several of the model’s steady-state conditions (see Appendix C.3), yields a 91% firm participation rate at the steady state (i.e.,  $M = 0.91$  in Table 2). This aligns closely with the numbers based on exit and entry rates of establishments, without directly targeting any of these moments. According to the Business Dynamics Statistics (BDS), the average annual exit and entry rates from 1977 to 2016 were 10.6% and 12.3%, respectively.<sup>19</sup>

**Shape Parameters in Pareto Distributions,  $\kappa$  and  $\omega$ :** We select  $\kappa = \omega = 3.4$  based on the work of Ghironi and Melitz (2005), who choose this shape parameter for the productivity distribution to align with the standard deviation of log U.S. plant sales, estimated

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<sup>18</sup>Appendix C offers an alternative estimation method based on the total number of employees from CES National Databases in the Bureau of Labor Statistics (BLS) as well. See Appendix C.1.

<sup>19</sup>The fixed cost in our model is regarded as a composite of capital and non-capital costs. In the literature, the capital-to-output cost ratio is estimated to be around 30%. According to Table 5 in Domowitz et al. (1988), the non-capital fixed cost-to-output ratio varies between 0.05 and 0.18 across industries. Summing these two components, our estimated  $\phi_f = 0.5547$  is at the upper end of this range.

at 1.67 by [Bernard et al. \(2003\)](#). In Appendix A.2, we provide a formula for our model-implied standard deviation of log revenues of upstream firms and compare with [Bernard et al. \(2003\)](#).

**Elasticity of Substitution,  $\gamma$  and  $\sigma$ :** We select  $\gamma = 4.3$  for the elasticity of substitution in the downstream market, following [Ghironi and Melitz \(2005\)](#) where 30% mark-up of price over cost is documented.

We choose  $\sigma = 3$  based on [Jones \(2011\)](#), who argue that the elasticity of substitution for upstream market products tend to be lower than in downstream markets. This number is also close to the number ( $\sigma = 3.79$ ) used by [Bernard et al. \(2003\)](#), who calibrate the elasticity of substitution to align with U.S. plant-level and macro trade data. There, the value of  $\sigma = 3.79$  is chosen to match the productivity and size advantages of U.S. exporters.<sup>20</sup> Our quantitative results turn out to be robust across different levels of  $\sigma$  around 3.

	Parameter Description	Value	Source
$\beta$	Discount factor	0.998	Standard.
$\eta$	Frisch labor supply elasticity	1	Standard.
$\gamma$	Elasticity of substitution (of downstream market)	4.3	From <a href="#">Ghironi and Melitz (2005)</a> : 30% mark-up of price over cost.
$\sigma$	Elasticity of substitution (of upstream market)	3	Lower elasticity of upstream market products as argued in <a href="#">Jones (2011)</a> .
$\alpha$	labor share in the upstream production function	0.6	Standard.
$\theta$	<a href="#">Calvo (1983)</a> price stickiness	0.75	Standard.
$\kappa$	Shape parameter: Pareto distribution of productivity	3.4	<a href="#">Ghironi and Melitz (2005)</a> .
$\omega$	Shape parameter: Pareto distribution of fixed cost	3.4	Keep it the same with the productivity distribution.
$\phi_f$	Fixed cost - steady state output ratio	0.5547	<b>Estimated</b> (Appendix C.3)
$\phi_g$	Government spending - output ratio	18%	<a href="#">Smets and Wouters (2007)</a> .

<sup>20</sup>Several studies, including [Ghironi and Melitz \(2005\)](#), [Bilbiie et al. \(2012\)](#), and [Fasani et al. \(2023\)](#), also adopt the elasticity of substitution around this number, following [Bernard et al. \(2003\)](#).

$\tau_\pi$	Taylor parameter (inflation)	1.5	Standard.
$\tau_y$	Taylor parameter (output)	0.15	Standard.
$\mu$	Long-run TFP growth rate	0.005	Match a yearly growth rate at 2%.
$\Pi$	Long-run inflation	1.02	Long-run inflation target at 2%.
$\rho_a$	Autoregression for TFP	0.7071	Excess TFP growth process' half-life of two quarters.
$\rho_c$	Autoregression for demand shock	0.98	The autocorrelation of the preference shock that affects the marginal utility of consumption estimated by Nakajima (2005).
$\rho_g$	Autoregression for government spending	0.87	Schmitt-Grohé and Uribe (2007).
$\rho_f$	Autoregression for fixed cost	0.9011	<b>Estimated</b> (Appendix C.3).
$\sigma_a$	SD for $\epsilon_a$	0.0064	Schmitt-Grohé and Uribe (2007).
$\sigma_c$	SD for $\epsilon_c$	0.017	The standard deviation of the preference shock estimated by Nakajima (2005) using U.S. data on consumption, labor, and output is 0.017.
$\sigma_g$	SD for $\epsilon_g$	0.016	Schmitt-Grohé and Uribe (2007).
$\sigma_f$	SD for $\epsilon_f$	0.0013	<b>Estimated</b> (Appendix C.3).
$\sigma_r$	SD for $\epsilon_r$	0.0025	25 basis points, following Fed practices.

Table 1: Calibrated parameters.

Variable	Value	Description
H	0.82	Mass of productivity-irrelevant firms.
M	0.91	Mass of firms operating in the market.
$R^B$	1.012	Gross risk-free rate.
$R^{J,*}$	1.296	Gross satiation rate.
$\tilde{F}^*$	0.72	Cutoff fixed cost-to-output ratio.
$\Delta$	1.0007	Price dispersion.
$\frac{W_t}{P_t A_t}$	0.51	Real wage.
$\frac{C_t}{Y_t}$	0.36	Consumption-to-output ratio.
$\frac{W_t N_t}{P_t Y_t}$	0.6	Labor cost-to-output ratio.
$\frac{L_t/P_t}{Y_t}$	0.46	Loan-to-output ratio.

Table 2: Steady state values.

## 3.2 Comparative Statics

In this section, we conduct comparative statics analyses on the steady-state equilibrium under varying parameter calibrations. This will illustrate the relationship between individual parameters and the internal mechanics of the model.

**Fraction of Operating Upstream Firms:** The steady-state proportion of active upstream firms, denoted as  $M$ , is described by  $1 - \Theta_M[1 - H]$ , as derived from equation (20). Figure 2 visualizes how  $M$  responds to shifts in model parameters:  $\kappa$ ,  $\omega$ ,  $\phi_f$ ,  $\beta$ ,  $\mu$ , and  $\Pi$ . We

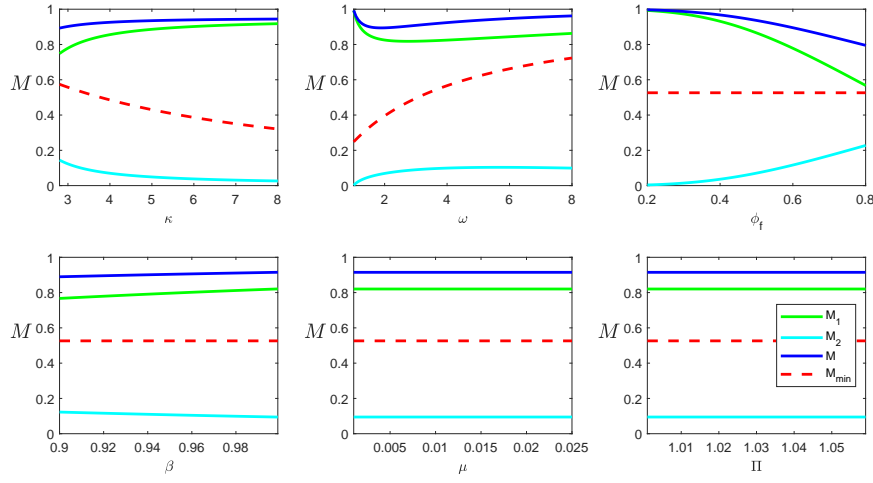


Figure 2: Comparative Statics:  $M$ .

*Notes:* Benchmark parameters are fixed as listed in Table 1. Ranges for  $\kappa$ ,  $\omega$ ,  $\phi_f$ ,  $\beta$ ,  $\mu$ , and  $\Pi$  are  $[2.8, 8]$ ,  $[1.01, 8]$ ,  $[0.2, 0.8]$ ,  $[0.9, 0.999]$ ,  $[0.001, 0.025]$ , and  $[1.001, 1.0709]$ , respectively. The red dashed line marks the minimum mass of active firms,  $M_{\min} = 1 - \Theta_M$ , attained when no firm is satiated,  $H_t = 0$ . We partition  $M$  into productivity-irrelevant  $M_1$  and jointly determined  $M_2$  components for various parameter values.

decompose  $M$  as follows:

$$\begin{aligned}
 M &= \text{Prob}(F < F^*) + \text{Prob}(F > F^*) \int_{F^*}^{\infty} \left( \frac{F_m}{F^*} \right)^{-\frac{\kappa[\alpha + \sigma(1-\alpha)]}{\sigma-1}} \frac{dH(F_m)}{1 - H(F^*)} \\
 &= \underbrace{H(F^*)}_{\equiv M_1} + \underbrace{\frac{\omega(\sigma-1)}{\kappa[\alpha + \sigma(1-\alpha)] + \omega(\sigma-1)}(1 - H(F^*))}_{\equiv M_2}.
 \end{aligned}$$

Here,  $M_1 = H(F^*)$  represents the mass of firms with sufficiently low fixed costs ( $F_{m,t} \leq F^*$ ) to remain active irrespective of their productivity.  $M_2$  comprises firms that are oper-

ational but not at the lowest fixed-cost tier; these firms do not operate if they draw a low productivity level.

The following key points can be drawn from Figure 2: (i) An increase in  $\kappa$  raises both  $M_1$  and  $M$  by narrowing the productivity distribution around its mean, thereby raising the lower bound of productivity and the likelihood of satiation for any given fixed cost; (ii) An increase in  $\omega$  manifests via two opposing effects on firm participation,  $M$ . On one hand, it raises the minimum fixed cost  $\frac{\omega-1}{\omega}F$ , thereby reducing  $M$ . On the other hand, it narrows the fixed-cost distribution around its mean  $F$ , potentially reducing the mass of high fixed-cost firms and increasing  $M$ . The total effect on  $M$  depends on the relative magnitudes of these two forces. Moreover, the satiation measure  $M_1$  typically declines as  $\omega$  increases due to an increased lower bound on fixed costs,  $\frac{\omega-1}{\omega}F$ , affecting firms that are typically satiated. These characteristics relating  $\omega$  and  $M$  are further elaborated in Figure D.6 in Appendix D, which explores the effect of other parameters on the functional relationship between  $M$  and each parameter; (iii) An increment in  $\phi_f$  shifts the fixed-cost distribution to the right, thereby reducing both  $M$  and  $M_1$ .

Following from equation (33), it is evident that the policy room  $\frac{R^B}{R^{J,*}}$  maintains an inverse relationship with  $M$ . Variations in the parameters will produce effects on the policy room that are opposite to their impacts on  $M$ , as documented in Figure D.7 in Appendix D.

**The Real Loan-to-Output Ratio:** At the steady state, the following inequality is derived from equations (21) and (32):

$$\phi_f (1 - \Theta_L) \leq \frac{L/P}{Y} = \phi_f \left[ 1 - \Theta_L (1 - H(F^*))^{\frac{\omega-1}{\omega}} \right] = \phi_f \left[ 1 - \Theta_L \left( \frac{\omega}{\omega+1} \frac{R^B}{R^{J,*}} \right)^{\omega-1} \right] \leq \phi_f ,$$

where the real loan-to-output ratio,  $\frac{L/P}{Y}$ , is a decreasing function of the policy room  $\frac{R^B}{R^{J,*}}$ , but increasing with respect to the satiation measure  $H(F^*)$ , and total firm participation,  $M$ .<sup>21</sup>

Figure 3 describes how  $\frac{L/P}{Y}$  varies with key model parameters:  $\kappa$ ,  $\omega$ ,  $\phi_f$ ,  $\beta$ ,  $\mu$ , and  $\Pi$ . Our observations can be summarized as follows: (i) An increase in  $\kappa$  raises firm participation  $M$ , as illustrated in Figure 2, and narrows the policy room  $\frac{R^B}{R^{J,*}}$ , as seen in equation (33) and Figure D.7, resulting on a higher aggregate loan demand; (ii) An increase in  $\omega$  gives rise to conflicting outcomes: it initially depresses firm participation  $M$  when  $\omega$  is below

<sup>21</sup>Note that  $M$  increases with  $H$  at the steady state as per equation (20).



a certain threshold, which can be attributed to an increase in the minimum fixed cost of entry,  $\frac{\omega-1}{\omega}F$ , as seen in Figure 2. However, this negative extensive margin effect is eventually counterbalanced by a positive intensive margin effect, where each active firm incurs a greater fixed cost, hence raising the real loan-to-output ratio; (iii) An increase in  $\phi_f$  results in a reduction of firm participation  $M$ , evident from Figure 2, thus reducing aggregate loan demand. As before, this decrease via the extensive margin is eventually neutralized by an increase via the intensive margin, where each active firm shoulders a higher fixed cost.<sup>22</sup> The dynamics between the policy room  $\frac{R^B}{R^{J,*}}$  and the real loan-to-output ratio  $\frac{L/P}{Y}$  are cap-

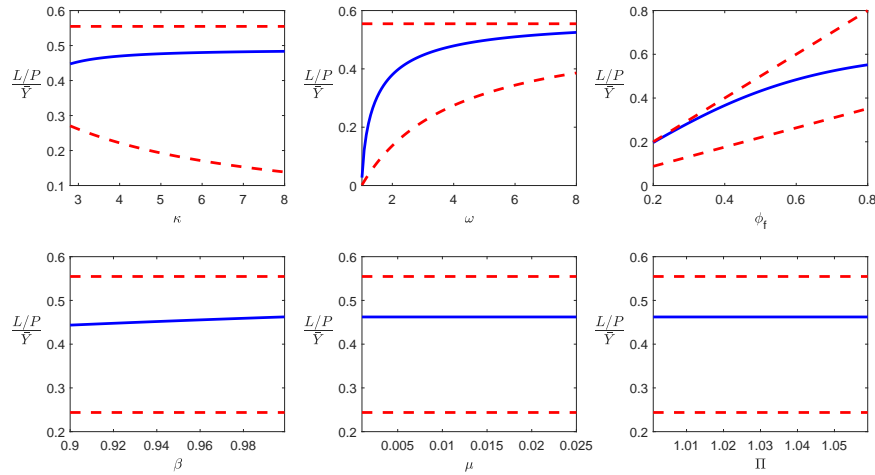


Figure 3: Comparative statistics: Output-scaled real lending.

*Notes:* The red-dashed lines indicate the upper and lower bounds for output-scaled lending, corresponding to  $\phi_f$  and  $\phi_f(1 - \Theta_L)$ , respectively.

tered in Figure 4. An increase in  $\phi_f$  or  $\omega$  lowers firm participation  $M$  and widens the policy room,  $\frac{R^B}{R^{J,*}}$ , with the net effect being an increase of aggregate loan issuance. In contrast, a rise in  $\kappa$  raises both  $M$  and  $\frac{L/P}{Y}$ , inducing a negative correlation with the policy room  $\frac{R^B}{R^{J,*}}$ .

<sup>22</sup>The functional relationship between  $\frac{L/P}{Y}$  and other parameters is further explored in Figure D.8.

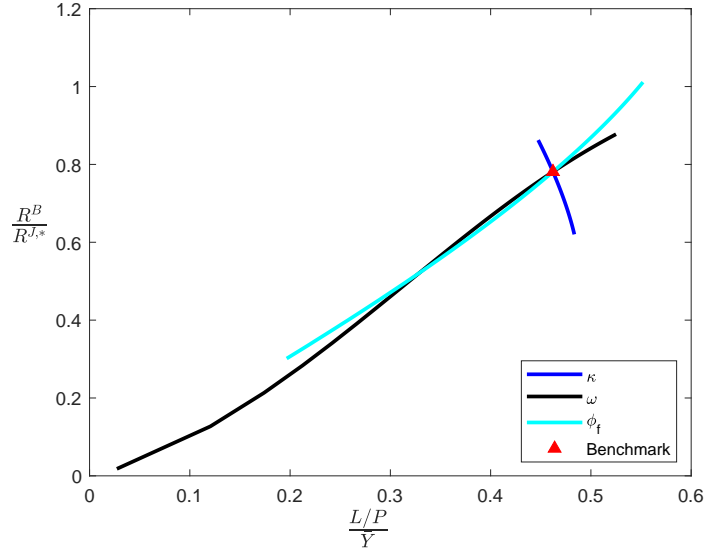


Figure 4: Policy power on output-scaled real lending.

*Notes:* This figure illustrates the co-movements between  $\frac{R^B}{R^{J,*}}$  and  $\frac{L/P}{Y}$  driven by variations in  $\kappa$ ,  $\omega$ , and  $\phi_f$ . The solid triangular marker denotes the steady-state value under benchmark calibration.

## 4 Quantitative Analysis

### 4.1 Supply vs. Demand Shocks

**Technology Shock** Figure 5a shows how a positive technology shock,  $u_{a,t}$ , affects various variables in our model. Following the shock, a group of previously inactive firms enters the market, boosting aggregate firm participation  $M_t$ , the measure of productivity-insensitive entrants  $H_t$ , and aggregate loans  $\frac{L_t}{P_t A_t}$ .<sup>23</sup> As participating firms pay their fixed costs in units of the final consumption good, the increase in firm entry contributes to an expansion in aggregate demand, as detailed in equation (29). An uptick in market participation typically depresses the real price of inputs,  $\frac{P_t^J}{P_t}$ , due to heightened competition, as expressed in equation (28). Yet in this case, the rising aggregate demand effect dominates, increasing real input prices along with labor demand  $N_t$  and real wages. This causes

<sup>23</sup>In Figures 5a and 5b, the percentage increase in the loan-to-output ratio,  $\frac{L_t/P_t}{Y_t}$ , is equal to  $\frac{L_t}{P_t A_t} \frac{A}{Y}$ , coming from a net rise in aggregate loan demand,  $\frac{L_t}{P_t A_t}$ . For small values of  $\phi_f$ , changes in loan demand around the steady state are negligible.

inflation  $\Pi_t$  and interest rates  $R_t^B$  to rise, thereby narrowing the policy room  $\frac{R_t^B}{R_t^{J,*}}$ .<sup>24</sup>

We also examine the technology shock's impact under varying levels of the fixed cost parameter,  $\phi_f$ . Higher entry costs mean a greater steady-state prevalence of inactive firms,  $1 - M$ . In such conditions, a positive  $u_{a,t}$  shock triggers substantial new firm entry and larger increases in  $M_t$  and  $H_t$ . The increase in aggregate demand brought by stronger entry is further amplified by the elevated fixed costs associated with a higher  $\phi_f$ . Consequently, there's a sharper initial increase in loan demand, real input prices, wages, and labor demand, followed by a faster reversion to steady-state levels due to increased competition. In this setting, inflation  $\Pi_t$  shows a more moderate response due to larger shifts in firm entry.<sup>25</sup>

These dynamics align with the traditional AD-AS framework as follows: (i) a positive technology shock moves the supply curve rightward; (ii) it leads to an outward movement of the demand curve due to increased loan and labor demands, causing more firm entry and further shifts in the supply curve; and (iii) when entry costs are high, more inactive firms enter the market after a positive supply shock. Consequently, both the aggregate supply and aggregate demand curves shift more extensively rightward, resulting in moderate inflation and increased output.

**Demand Shock** Figure 5b illustrates the effects of a consumption demand shock,  $u_{c,t}$ . The figure exhibits impulse responses that are qualitatively analogous to Figure 5a. Specifically, a positive shock to  $u_{c,t}$  prompts an increase in firm entry that results in an expansion of the aggregate supply capacity of the economy.<sup>26</sup>

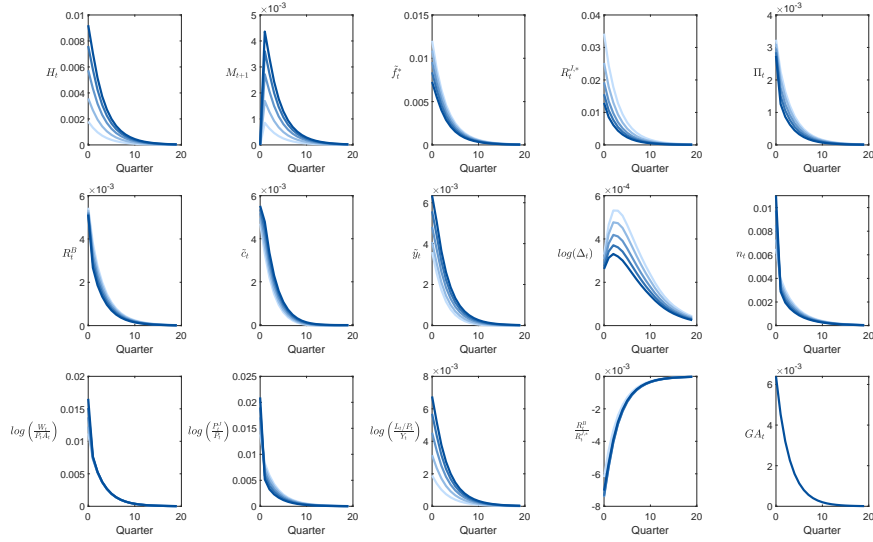
In summary, our model highlights the reciprocal relationship between supply and demand that exists as a result of endogenous firm entry. Accordingly, the initial origin of the shock—be it supply- or demand-driven—yields no qualitative distinctions in the behavior of the key variables within our model. Nonetheless, economies with a larger pool of potential new entrants generate stronger responses to shocks in the form of larger output and moderate inflation movements.

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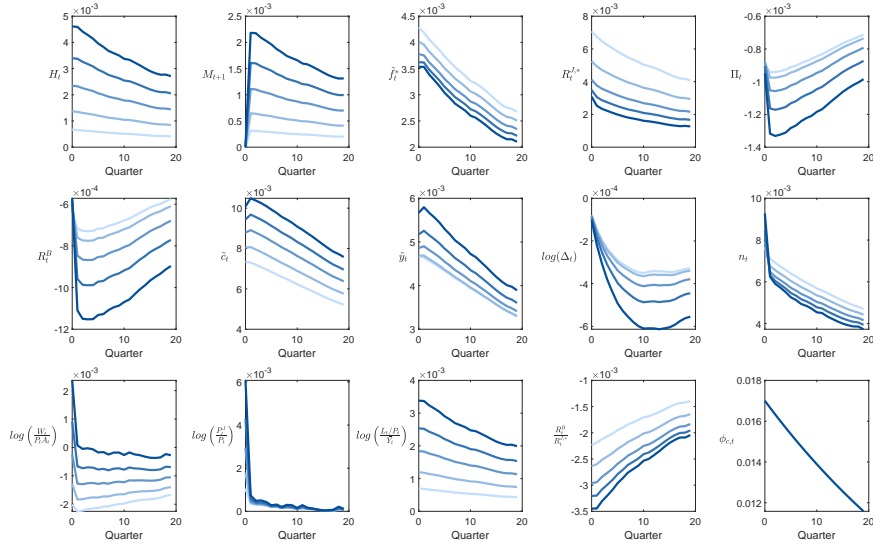
<sup>24</sup>This result is consistent with the positive correlation between the policy room,  $\frac{R_t^B}{R_t^{J,*}}$ , and firm participation,  $M_t$ , outlined in equation (33)

<sup>25</sup>This observation is consistent with the findings of Cecioni (2010), who argue that greater firm entry can mitigate inflationary pressures in the U.S. economy.

<sup>26</sup>Note one difference between Figures 5a and 5b: with our demand shocks, inflation drops due to stronger effects of additional firm entry on aggregate supply. Also, note that demand shocks are more persistent since  $\rho_c \gg \rho_a$  in our calibration.



(a) Impulse response functions to TFP shock.



(b) Impulse response functions to demand shock.

*Notes:* The figures display the impulse response functions to supply and demand shocks. Panel (a) shows the response to a one standard deviation shock (0.0064) in  $u_{a,t}$ , which increases the growth rate of the average productivity for upstream firms. Panel (b) shows the response to a one standard deviation shock (0.017) in  $u_{c,t}$ , the demand shock. The gradient blue lines denote the responses under calibrations with varying  $\phi_f$ . From light blue to dark blue,  $\phi_f$  values are 0.35, 0.45, 0.5547 (benchmark), 0.65, and 0.75. The following variables are plotted in deviations from their steady states:  $H$ ,  $M$ ,  $R^B$ ,  $\Pi$ , and  $R^{J,*}$ . The remaining variables are plotted in log deviations from their steady states (in lower case letters or with a log).  $\Delta$  represents the price dispersion for the downstream products.

**Other Shocks** In Appendix D.2, impulse response functions are presented for fixed cost shocks  $u_{f,t}$  (Figure D.9), monetary policy shocks  $\varepsilon_{r,t}$  (Figure D.10), and government spending shocks  $u_{g,t}$  (Figure D.11). A positive fixed cost shock induces falls in firm entry  $M_t$  and the satiation measure  $H_t$ . This decline is attributed to the elevated productivity cutoff  $\varphi_{m,t}^*$ , as specified in equation (14), which rises for each firm type  $m$  due to increased entry costs. This shock has dual, opposing impacts on aggregate demand: First, reduced firm participation diminishes fixed equipment demand at the extensive margin, thereby contracting aggregate demand. Second, the increased fixed costs boost demand from incumbent firms, thereby augmenting aggregate demand at the intensive margin. Under the model’s benchmark calibration (i.e.,  $\phi_f = 0.5547$ ), the latter effect prevails, leading to a net expansion in output. This subsequently results in an increase in equilibrium levels of labor demand, real wages, and inflation.

A positive monetary policy shock generates an impulse response function akin to that produced by a consumption demand shock. A rise in monetary policy rates lowers aggregate participation  $M_t$ , which in turn decrease loan demand, inflation, real wages, and production levels. A positive government spending shock, depicted in Figure D.11, crowds out consumption via higher real interest rates while simultaneously reducing inflation through increased participation by upstream firms, as evidenced by rises in both  $M_t$  and  $H_t$ . The government spending multiplier is amplified under higher values of  $\phi_f$ , which is attributable to stronger firm entry following the shock.

## 4.2 Intensive vs. Extensive Margin in Labor Adjustment

Note that changes in aggregate labor  $N_t$  as specified in equation (25) are attributable to two primary factors: (i) variations in each operating firm’s labor demand, denoted  $N_{mv,t}$ , over time —referred to as intensive margin adjustment; and (ii) fluctuations in the number of active upstream firms  $M_t$  across business cycles —known as extensive margin adjustment. The aggregate labor  $N_t$  is formally expressed in equation (35) as:

$$N_t = \int_0^1 \int_{v \in \Omega_{m,t}} N_{mv,t} \, dv \, dm, \quad (35)$$

where the individual labor demand  $N_{mv,t}$  derives from equation (A.16). We now proceed to consider an upstream firm  $(m, v)$  operating across two periods  $t$  and  $t + \iota$ , where  $\iota \geq 1$ .

Utilizing equation (A.16), we define:

$$g_{t,t+\iota}^{\text{Density}} \equiv \frac{N_{mv,t+\iota} - N_{mv,t}}{N_{mv,t}} = \left[ \frac{1 + \Theta_4 \cdot H_{t-1}}{1 + \Theta_4 \cdot H_{t+\iota-1}} \right]^{\frac{\sigma}{(\sigma-1)\alpha}} \left( \frac{\frac{Y_{t+\iota} \Delta_{t+\iota}}{A_{t+\iota}}}{\frac{Y_t \Delta_t}{A_t}} \right)^{\frac{1}{\alpha}} - 1, \quad (36)$$

which represents the percentage change between periods  $t$  and  $t + \iota$  in an individual firm  $(m, v)$ 's labor demand  $N_{mv,t}$ , contingent upon the firm's operation in both periods. Importantly,  $g_{t,t+\iota}^{\text{Density}}$  is solely a function of aggregate variables, independent of the indices  $(m, v)$ . We term  $g_{t,t+\iota}^{\text{Density}}$  as the ‘‘intensive margin’’ adjustment in labor demand.

From equation (25), we can derive an expression for the percentage change in aggregate labor,  $N_t$ , denoted as  $g_{t,t+\iota}^N$ <sup>27</sup>:

$$g_{t,t+\iota}^N \equiv \frac{N_{t+\iota} - N_t}{N_t} = g_{t,t+\iota}^{\text{Density}} + (1 + g_{t,t+\iota}^{\text{Density}}) \cdot g_{t,t+\iota}^{\text{Entry}}, \quad (37)$$

where  $g_{t,t+\iota}^{\text{Density}}$  is defined as in equation (36) and  $g_{t,t+\iota}^{\text{Entry}}$  is given by

$$g_{t,t+\iota}^{\text{Entry}} = \frac{(H_{t+\iota-1} - H_{t-1}) + \frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)]+(\omega-1)(\sigma-1)}(H_{t-1} - H_{t+\iota-1})}{H_{t-1} + \frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)]+(\omega-1)(\sigma-1)}(1 - H_{t-1})}. \quad (38)$$

We interpret  $g_{t,t+\iota}^{\text{Entry}}$  as the extensive margin adjustment in labor, triggered by changes in firm entry. According to equation (37), the total percentage change in aggregate labor comprises both intensive and extensive margin adjustments.

Figures 6 and 7 portray how intensive and extensive margins' elements respond, respectively, to different shocks. For example, for a positive fixed cost shock  $u_{f,t}$ , we note that (i) a negative extensive margin adjustment due to the exit of less competitive firms, and (ii) an increase in per-firm labor demand corresponding to higher aggregate output, as evidenced in Figure D.9.

In contrast, a consumption demand shock  $\phi_{c,t}$  generates positive adjustments on both margins due to increased market entry and aggregate output (see Figure 5b). The extensive margin effect becomes more salient under higher  $\phi_f$ , while the intensive margin exhibits a non-monotonic behavior. Initially, individual firms require more workers, but as market competition intensifies, labor demand flattens, as corroborated by Figure D.9.

<sup>27</sup>The derivation is provided in Appendix A.

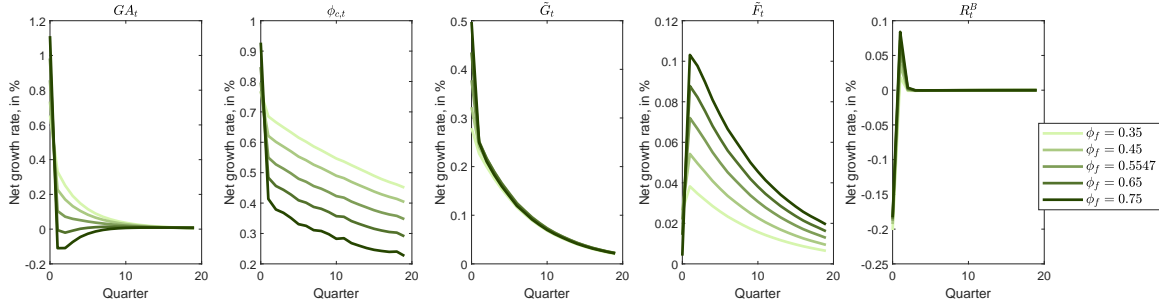


Figure 6: Decomposition of labor growth rate under different shocks: isolines on intensive margin.

*Notes:* Figures illustrate employment growth rate relative to pre-shock employment level. Gradient green lines indicate intensive margin responses with varying fixed cost parameter  $\phi_f$  values. Growth rates are reported in net percentage terms.

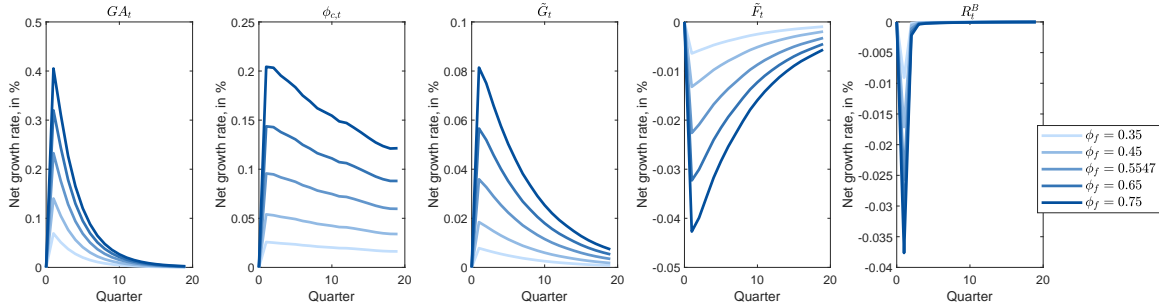


Figure 7: Decomposition of labor growth rate under different shocks: isolines on extensive margin.

*Notes:* Figures illustrate employment growth rate relative to pre-shock employment level. Gradient blue lines indicate extensive margin responses with varying fixed cost parameter  $\phi_f$  values. Growth rates are reported in net percentage terms.

### 4.3 Multipliers and the Policy Room

We now examine the influence of “initial policy room levels” on the responses of aggregate variables to shocks, commonly termed in the literature as shock multipliers. To obtain the value of multipliers outside the steady state, we simulate the model over a span of  $T = 10,000$  periods, selecting 500 unique realizations denoted as  $\mathbb{Y}^{\text{original}}$ . For each selected realization, we extend the model dynamics up to  $h = 4$  periods ahead based on two different scenarios: (i) a situation with no additional shock, which results in the original time series  $\left\{ \mathbb{Y}_{t+h}^{\text{original}} \right\}_{h=0}^{h=4}$ ; and, (ii) a case where the shock of interest is realized to be higher by a one standard deviation, giving rise to time series  $\left\{ \mathbb{Y}_{t+h}^{\text{shock}} \right\}_{h=0}^{h=4}$ . The multiplier can subsequently

be computed as  $\frac{|\bar{Y}_{t+h}^{\text{shock}} - \bar{Y}_{t+h}^{\text{original}}|}{\sigma(\text{shock})}$  for horizons ranging from  $h = 0$  to  $h = 4$ . Figure 8 plots the

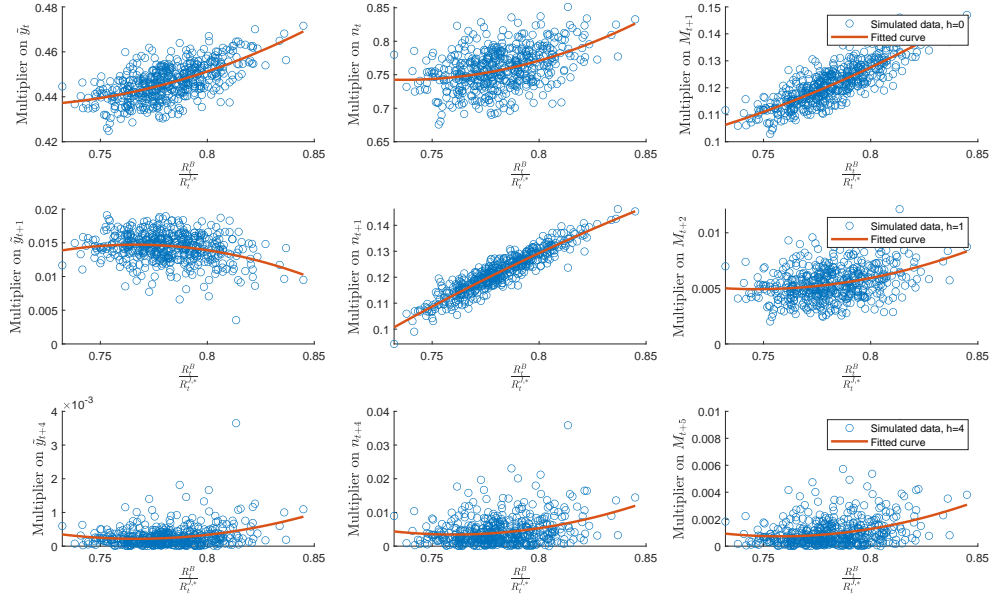


Figure 8: Scatter plot between policy room and monetary policy multipliers.

*Notes:* Figures plot the relationship between policy room and monetary policy multipliers on output (in logs), labor (in logs), and next period mass of operating firms (in levels). We consider the next period’s mass of operating firms since the firms paying the fixed cost at  $t$  will operate on the market at  $t + 1$ . Figures in the first to third rows display the contemporaneous multipliers ( $h = 0$ ), multipliers after 1 quarter ( $h = 1$ ), and multipliers after 4 quarters ( $h = 4$ ) correspondingly. The blue circles represent the result from each simulation based on solutions from the third-order perturbation method. The red solid lines are fitted second-order polynomials.

relationship between multipliers and initial policy room levels. The key findings are:

1. At  $h = 0$ , the multipliers for output and labor positively correlate with initial policy room levels. This effect is due to the higher rate of firm entry (which in turn raises equipment purchases) in response to a monetary shock when initial policy room is larger, consistent with Corollary 1. We will test this channel in the data shortly.
2. At  $h = 1$ , although the multipliers decline due to the shock’s lack of persistence, the positive correlation with the initial policy room remains. This is explained by an increased number of firms in the market and an associated rise in supply.
3. At  $h = 4$ , multipliers approach zero, attributable to the lack of shock persistence.



In summary, the policy room serves as a sufficient statistic for equilibrium firm entry and is positively correlated with the multipliers for output, labor, and firm entry in response to monetary shocks. Further details can be found in Figures D.13 and D.14<sup>28</sup> in Appendix D, which relate closely to the discussion here.

## 5 Empirical Analysis

In this section, we empirically test the key implication from Corollary 1 and Section 4.3: a higher initial level of policy room enhances the efficacy of monetary policy, as it allows for a greater endogenous response in firm entry, affecting both aggregate demand and supply. Appendix C.4 provides two alternative methods to recover the policy room  $\frac{R_t^B}{R_t^{J,*}}$  based on different equilibrium conditions of the model. These methods can utilize data on labor markets (e.g., various employment measures) or firm participation (e.g., the number of active establishments). Here, we focus on the policy room derived from firm participation data (Version 2 in Appendix C.2).<sup>29</sup> Our benchmark local projection à la Jordà (2005) is specified as:

$$\begin{aligned} \tilde{y}_{t+h} = & \sum_{q=1}^Q \beta_{\tilde{y},q}^{(h)} \tilde{y}_{t-q} + \sum_{q=1}^Q \beta_{R,q}^{(h)} \widehat{r_{t-q}^B - r_{t-q}^{J,*}} + \sum_{q=0}^Q \gamma_q^{(h)} \text{controls}_{t-q} \\ & + \sum_{q=0}^Q \beta_{0,q}^{(h)} \epsilon_{t-q} + \sum_{q=0}^Q \beta_{0R,q}^{(h)} \epsilon_{t-q} \times \widehat{r_{t-q-1}^B - r_{t-q-1}^{J,*}} + u_{t+h}^{(h)}, \end{aligned} \quad \text{for } h = 0, \dots, H,$$

with the following components:

1. Monetary policy shocks,  $\epsilon_t$ : Acosta (2023)'s extension of Romer and Romer (2004) monetary policy shocks. In Appendix E, we present results based on Wieland and Yang (2020)'s extended series of Romer and Romer (2004). These shocks are, by construction, exogenous. Coefficient  $\beta_{0,0}^{(h)}$  captures the impact of monetary policy shocks when the policy room is at its steady-state value.
2. Policy room measure,  $\widehat{r_t^B - r_t^{J,*}}$ : Log-deviation of the policy room  $\frac{R_t^B}{R_t^{J,*}}$  from the steady state, recovered using data on the total number of establishments from the

<sup>28</sup>Figure D.14 in Appendix D documents the relation between the policy room and the government spending multiplier, which is similar to the case of monetary policy in Figure 8.

<sup>29</sup>Results based on labor market variables (Version 1 in Appendix C.1) are also provided, with a comparison of the two approaches in Appendix E.

Quarterly Census of Employment and Wages (QCEW) in Appendices C.2 and C.4. We interact the monetary policy shock series with the lagged policy room variable to measure the additional effectiveness of monetary policy shocks when the policy room widens, as captured by the coefficient  $\beta_{0R,0}^{(h)}$ .<sup>30</sup>

3. Controls and variables of interest: In the benchmark regression, we control for the lags of the dependent variable, the policy room, the monetary policy shock, and the interaction between the latter two. The variable vectors  $\{\text{controls}_{t-q}\}_0^Q$  encompass any additional controls added to the regression, which, in our benchmark specification, include the current and four lags of the federal funds rates. As the dependent variable  $\tilde{y}_t$ , we use log consumption, log output, the unemployment rate (in percentage), and the log of the number of establishments (QCEW).
4. Number of lags  $Q$ : In our benchmark specification, we set the number of lags to four, corresponding to one year of lagged data at a quarterly frequency. In Appendix E, we discuss the robustness of our results across different lag lengths.

Figure 9 shows the impulse response functions of several variables under our benchmark regression specification. Consistent with our theory, a wider policy room significantly increases the potency of monetary policy shocks. Panel (a) demonstrates that an increase of one standard deviation (approximately 2 percentage points) in the log-policy room decreases output by up to an additional three percentage points in response to a one standard deviation (approximately 25 basis points) monetary tightening shock. Panel (d) provides further evidence supporting the model’s implied interplay between supply and demand mechanics driving the differences in the effectiveness of monetary policy shocks. When the economy suffers a monetary tightening shock under a wider policy room, firm entry tends to contract further within a period of one and a half years.

**With Additional Controls** We add more controls to the benchmark regression specification to test the robustness of our results. The additional controls include four lags of the oil price growth rate, four lags of the long-term interest rate, four lags of the consumption growth rate, four lags of the GDP deflator, and four lags of the shadow federal funds rate from Wu and Xia (2016). Figure 10 shows that the additional controls produce little to no

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<sup>30</sup>We interact the monetary policy shocks with the lagged policy room measure to avoid potential endogeneity issues.

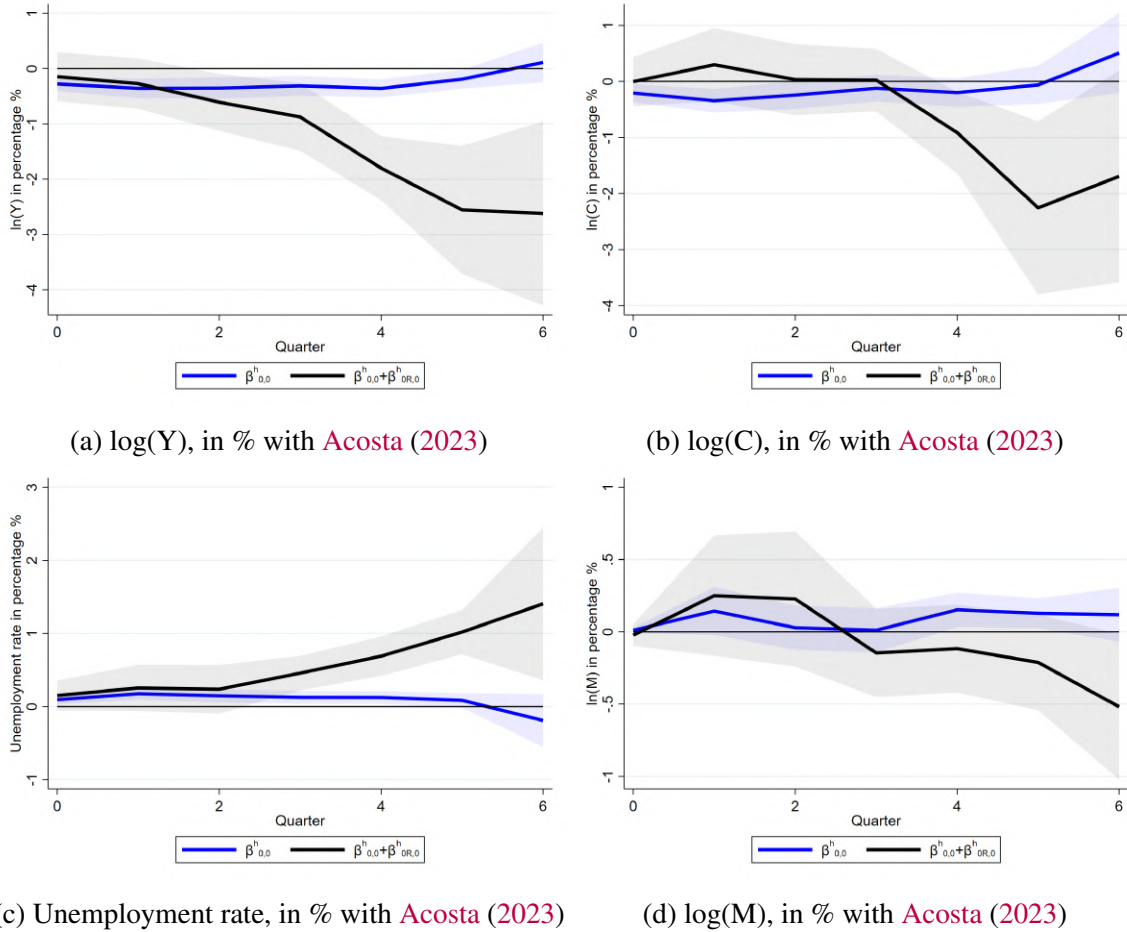


Figure 9: Local projection with policy room from Version 2.

*Notes:* The impulse response functions are based on the benchmark regression specification, which controls for the current and four lags of the federal funds rate. The IRFs display the response to a one standard deviation (29 basis points) positive monetary policy shock and a one standard deviation (2 percentage points) increase in the log policy room, constructed based on the Version 2 measure of the variable, utilizing the number of establishments from the Quarterly Census of Employment and Wages (QCEW) dataset (see Appendix C.2). The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

difference in the impulse responses of the selected variables compared to the benchmark specification displayed in Figure 9.

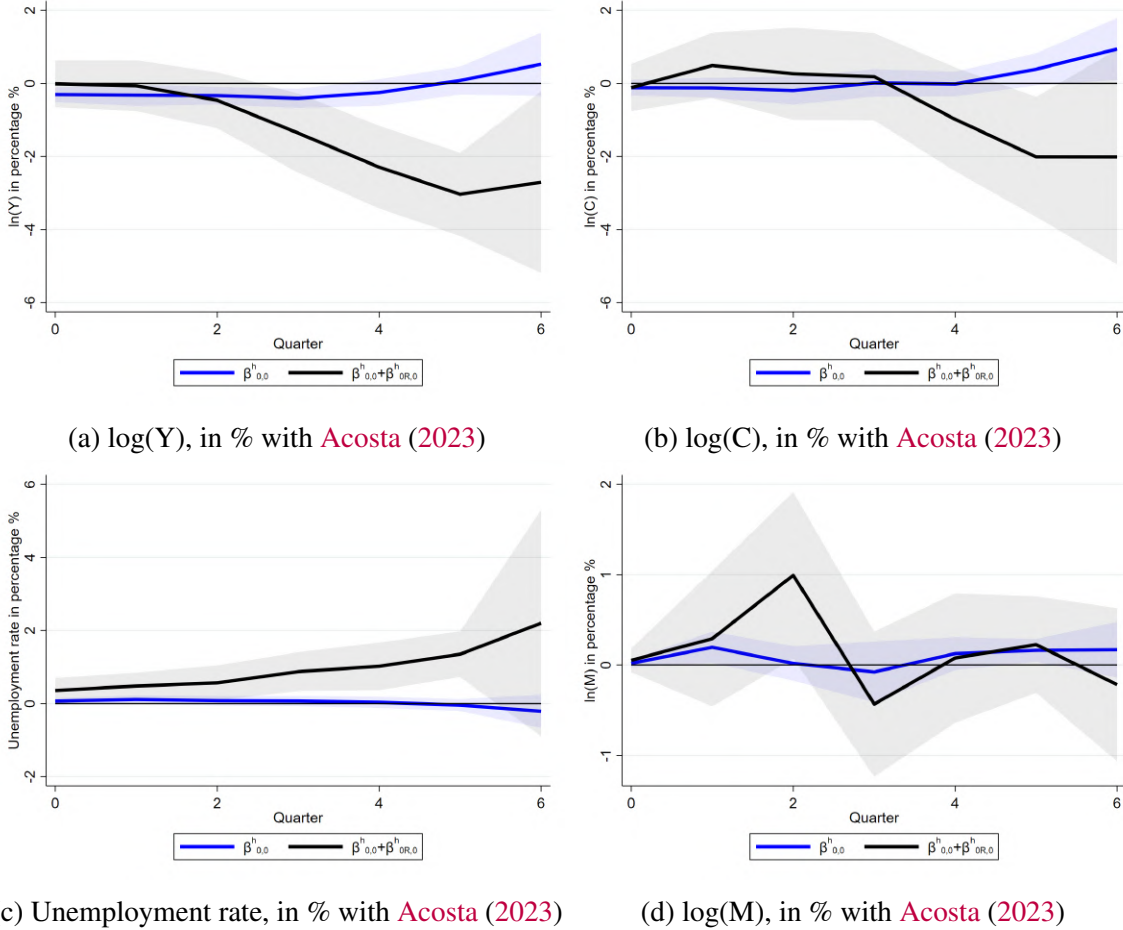


Figure 10: Local projection with policy room from Version 2 and additional controls.

*Notes:* The impulse response functions extend the benchmark regression specification with the addition of the following controls: four lags of the oil price growth rate, four lags of the long-term interest rate, four lags of the consumption growth rate, four lags of the GDP deflator, and four lags of the shadow federal funds rate from Wu and Xia (2016). The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

**Additional Robustness** In Appendix E, we provide results based on a different method to recover the policy room  $\widehat{r_t^B - r_t^{J*}}$ , using employment data from the CES National Databases in the Bureau of Labor Statistics (BLS) and monetary policy shocks from Wieland and Yang

(2020). The results remain qualitatively similar to those in Figure 9.

## 6 Conclusion

In this paper, we develop a macroeconomic model with endogenous firm entry. Based on a dual-industry (i.e., upstream and downstream industries) model, we tractably embed the dynamics of endogenous firm entry within a New-Keynesian framework. In our model, upstream firms face stochastic fixed entry costs, denominated in the final consumption good. These firms are also constrained by cash-in-advance requirements and thus rely on capital markets for financing their fixed costs. Downstream firms, on the other hand, are subject to nominal rigidities. Our analysis reveals that demand shocks increase firm profitability and entry, thereby expanding the economy's aggregate supply. In turn, this increased participation stimulates additional demand for the final good, as firms seek to finance their entry via loans. This process initiates a self-reinforcing cycle, rendering the relationship between demand and supply non-separable under general circumstances. As a result, conventionally defined 'supply' and 'demand' shocks can induce comparable patterns of business cycle co-movements. In particular, supply shifts, resulting from the entry of new firms, lead to disinflationary pressures alongside an increase in output.

We identify a critical threshold of the policy rate for each entry fixed cost level, termed the Satiation Bound (SB). At this threshold, all firms with identical entry fixed costs fully engage in production, rendering monetary policy ineffective in further spurring economic growth through new firm participation. Based on this concept, we introduce a metric known as the "policy room", which represents the difference between the current policy rate and the average SB across firms. It turns out that there is a strong positive correlation between a room for additional firm entry, monetary policy efficacy, and the policy room: monetary policy becomes a more effective stabilizer under a higher policy room level, since there is a larger room for changes in the firm entry rate that affects aggregate supply.

We further analyze changes in aggregate variables such as labor, breaking them down into two components: the 'extensive' margin, involving new firm entries, and the 'intensive' margin, related to activities of incumbent firms. We show that a wider policy room makes firm entry decisions more responsive to changes in the policy rate, leading to higher policy multipliers.

While stylized and analytical in nature, our model provides a novel implication which we confirm with our empirical exercises: when the policy room narrows, the extensive

margin of monetary policy transmission wanes, resulting in lower output multipliers and reduced firm entry. Therefore, understanding the drivers of firm participation becomes key to discerning how demand and supply interact at business cycle frequencies.

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## A Derivation and Proofs

### A.1 Detailed Derivation in Section 2.2

**Derivation of equations (12) and (13)** The price setting of a firm  $(m, v)$  is given by

$$P_{mv,t}^J = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right) W_t \varphi_{mv,t}^{-\frac{1}{\alpha}} J_{mv,t}^{\frac{1-\alpha}{\alpha}} = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right) W_t \varphi_{mv,t}^{-\frac{1}{\alpha}} [(P_{mv,t}^J)^{-\sigma} \Gamma_t^J]^{\frac{1-\alpha}{\alpha}},$$

in which we can solve for  $P_{mv,t}^J$  as

$$(P_{mv,t}^J)^{\frac{\alpha + \sigma(1-\alpha)}{\alpha}} = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right) W_t \varphi_{mv,t}^{-\frac{1}{\alpha}} (\Gamma_t^J)^{\frac{1-\alpha}{\alpha}},$$

from which we obtain

$$P_{mv,t}^J = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right)^{\frac{\alpha}{\alpha + \sigma(1-\alpha)}} W_t^{\frac{\alpha}{\alpha + \sigma(1-\alpha)}} \varphi_{mv,t}^{-\frac{1}{\alpha + \sigma(1-\alpha)}} (\Gamma_t^J)^{\frac{(1-\alpha)}{\alpha + \sigma(1-\alpha)}}. \quad (\text{A.1})$$

To get the revenue function  $r_{mv,t}$ , we start from

$$P_{mv,t}^J J_{mv,t} = \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right) W_t \varphi_{mv,t}^{-\frac{1}{\alpha}} J_{mv,t}^{\frac{1}{\alpha}},$$

which leads to

$$\begin{aligned} r_{mv,t} &= (1 + \zeta^J) P_{mv,t}^J J_{mv,t} = \left( \frac{\sigma}{(\sigma - 1)\alpha} \right) W_t N_{mv,t} = (1 + \zeta^J) P_{mv,t}^J \left( \frac{P_{mv,t}^J}{P_t^J} \right)^{-\sigma} J_t \\ &= (1 + \zeta^J) (P_{mv,t}^J)^{1-\sigma} \Gamma_t^J = (1 + \zeta^J) \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right)^{\frac{\alpha(1-\sigma)}{\alpha + \sigma(1-\alpha)}} W_t^{\frac{\alpha(1-\sigma)}{\alpha + \sigma(1-\alpha)}} \varphi_{mv,t}^{-\frac{(1-\sigma)}{\alpha + \sigma(1-\alpha)}} (\Gamma_t^J)^{\frac{1}{\alpha + \sigma(1-\alpha)}}. \end{aligned} \quad (\text{A.2})$$

Finally, we obtain the formula for the profit  $\Pi_{mv,t}^J$ , which is given by

$$\Pi_{mv,t}^J = r_{mv,t} - W_t N_{mv,t} - R_{t-1}^J P_{t-1} F_{m,t-1} = \frac{\alpha + \sigma(1 - \alpha)}{\sigma} r_{mv,t} - R_{t-1}^J P_{t-1} F_{m,t-1}.$$

**Calculating  $P_{m,t}^J$  in (6): the price aggregator for firms of fixed  $F_{m,t-1}$**  From our notation in (6), we know that among firms with fixed cost  $F_{m,t-1}$ , a set of operating ones at  $t$  would be given by  $\Omega_{m,t} = \{ \varphi_{mv,t} \in [\max \{ \varphi_{m,t}^* (\frac{\kappa-1}{\kappa}) A_t \}, \infty] \}$ . The cumulative dis-

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tribution function of productivities of upstream firms that decide to produce is  $\frac{\Psi(\varphi_{m,t})}{1-\Psi(\varphi_{m,t}^*)}$ , a truncated Pareto distribution which is itself a Pareto distribution. With the individual firm  $(m, v)$ 's pricing equation (A.1), we now can compute the aggregate price of upstream firms with fixed cost  $F_{m,t-1}$  as:

$$\left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} = M_{m,t} \cdot \int_{\max\{\varphi_{m,t}^*, (\frac{\kappa-1}{\kappa})A_t\}}^{\infty} \left(\frac{P_{mv,t}^J}{P_t}\right)^{1-\sigma} \frac{d\Psi(\varphi_{mv,t})}{1-\Psi(\varphi_{m,t}^*)} \quad (\text{A.3})$$

$$\begin{aligned} &= \int_{\max\{\varphi_{m,t}^*, (\frac{\kappa-1}{\kappa})A_t\}}^{\infty} \left(\frac{P_{mv,t}^J}{P_t}\right)^{1-\sigma} d\Psi(\varphi_{mv,t}) \\ &= \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa-1}{\kappa}\right)^{\frac{(\sigma-1)}{\alpha+\sigma(1-\alpha)}} \left(\frac{W_t}{P_t A_t}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left[\left(\frac{\kappa-1}{\kappa}\right)A_t\right]^{\frac{(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \\ &\quad \cdot \left(\frac{\Gamma_t^J}{(P_t^J)^\sigma A_t}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{P_t^J}{P_t}\right)^{\frac{(1-\alpha)(1-\sigma)\sigma}{\alpha+\sigma(1-\alpha)}} \int_{\max\{\varphi_{m,t}^*, (\frac{\kappa-1}{\kappa})A_t\}}^{\infty} \varphi_{mv,t}^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} d\Psi(\varphi_{mv,t}) \\ &= \Theta_1 \left(\frac{W_t}{P_t A_t}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{Y_t \Delta_t}{A_t}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{P_t^J}{P_t}\right)^{\frac{(1-\alpha)(1-\sigma)\sigma}{\alpha+\sigma(1-\alpha)}} \max\left\{\frac{\varphi_{m,t}^*}{(\frac{\kappa-1}{\kappa})A_t}, 1\right\}^{-\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\alpha+\sigma(1-\alpha)}} \\ &= \Theta_1 \left(\frac{W_t}{P_t A_t}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{Y_t \Delta_t}{A_t}\right)^{\frac{(1-\alpha)(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{P_t^J}{P_t}\right)^{\frac{(1-\alpha)(1-\sigma)\sigma}{\alpha+\sigma(1-\alpha)}} \\ &\quad \cdot \min\left\{\left(\frac{R_{t-1}^J P_{t-1} F_{m,t-1}}{E_{t-1} [\xi_t \cdot \Xi_t] \left[\left(\frac{\kappa-1}{\kappa}\right)A_t\right]^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}}\right)^{-\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\sigma-1}}, 1\right\}, \end{aligned} \quad (\text{A.4})$$

where we define

$$\Theta_1 = \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa-1}{\kappa}\right)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}\right).$$

**Reexpressing  $\Xi_t$  in equation (13)** Combining equation (13) with  $\Gamma_t^J = (P_t^J)^\sigma Y_t \Delta_t$ , we obtain

$$\begin{aligned} \Xi_t &= \frac{\alpha+\sigma(1-\alpha)}{\alpha(\sigma-1)} \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{-\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa-1}{\kappa}\right)^{\frac{\alpha(\sigma-1)}{\alpha+\sigma(1-\alpha)}} \left(\frac{P_t^J}{P_t}\right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \\ &\quad \cdot \left(\frac{W_t}{A_t P_t}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left[\left(\frac{\kappa-1}{\kappa}\right)A_t\right]^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} P_t (Y_t \Delta_t)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \\ &= \Theta_2 \cdot \left(\frac{P_t^J}{P_t}\right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left(\frac{W_t}{A_t P_t}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left[\left(\frac{\kappa-1}{\kappa}\right)A_t\right]^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} P_t (Y_t \Delta_t)^{\frac{1}{\alpha+\sigma(1-\alpha)}}, \end{aligned} \quad (\text{A.5})$$

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where we define

$$\Theta_2 = \frac{\alpha + \sigma(1 - \alpha)}{\alpha(\sigma - 1)} \left( \frac{(1 + \zeta^J)^{-1}\sigma}{(\sigma - 1)\alpha} \right)^{-\frac{\sigma}{\alpha + \sigma(1 - \alpha)}} \left( \frac{\kappa - 1}{\kappa} \right)^{\frac{\alpha(\sigma - 1)}{\alpha + \sigma(1 - \alpha)}}.$$

**Derivation of  $P_t^J$  in (19)** We start from the full satiation threshold of the fixed cost  $F_{t-1}^*$  defined in Proposition 2:

$$\begin{aligned} F_{t-1}^* &= \frac{E_{t-1} [\xi_t \cdot \Xi_t] \left[ \left( \frac{\kappa - 1}{\kappa} \right) A_t \right]^{\frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)}}}{R_{t-1}^J P_{t-1}} \tag{A.6} \\ &= \Theta_2 E_{t-1} \left[ \xi_t \left( \frac{P_t^J}{P_t} \right)^{\frac{\sigma}{\alpha + \sigma(1 - \alpha)}} \left( \frac{W_t}{A_t P_t} \right)^{\frac{\alpha(1 - \sigma)}{\alpha + \sigma(1 - \alpha)}} \left[ \left( \frac{\kappa - 1}{\kappa} \right) A_t \right]^{\frac{(\sigma - 1)(1 - \alpha)}{\alpha + \sigma(1 - \alpha)}} \left( \frac{\Pi_t (Y_t \Delta_t)^{\frac{1}{\alpha + \sigma(1 - \alpha)}}}{R_{t-1}^J} \right) \right], \end{aligned}$$

where the second equality is from equation (A.5). From (14) and (A.6), we obtain

$$\varphi_{m,t}^* = \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{\frac{\alpha + \sigma(1 - \alpha)}{\sigma - 1}} \left( \frac{\kappa - 1}{\kappa} \right) A_t, \tag{A.7}$$

and

$$R_{m,t-1}^{J,*} = \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{-1} R_{t-1}^J. \tag{A.8}$$

From (15), we obtain

$$M_{m,t} = \min \left\{ \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{-\left( \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\sigma - 1} \right)}, 1 \right\}. \tag{A.9}$$

Using equation (A.3) and (A.6), we obtain

$$\begin{aligned} \left( \frac{P_{m,t}^J}{P_t} \right)^{1 - \sigma} &= \Theta_1 \cdot \left( \frac{W_t}{P_t A_t} \right)^{\frac{\alpha(1 - \sigma)}{\alpha + \sigma(1 - \alpha)}} \left( \frac{P_t^J}{P_t} \right)^{\frac{(1 - \alpha)(1 - \sigma)\sigma}{\alpha + \sigma(1 - \alpha)}} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{(1 - \alpha)(1 - \sigma)}{\alpha + \sigma(1 - \alpha)}} \\ &\quad \cdot \min \left\{ \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{-\left( \frac{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)}{\sigma - 1} \right)}, 1 \right\}. \end{aligned} \tag{A.10}$$

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We rearrange equation (6) as:

$$\begin{aligned}
 \left(\frac{P_t^J}{P_t}\right)^{1-\sigma} &= \int_0^1 \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} dm \\
 &= Prob(F_{m,t-1} \leq F_{t-1}^*) E_t \left[ \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} \mid F_{m,t-1} \leq F_{t-1}^* \right] \\
 &\quad + Prob(F_{m,t-1} > F_{t-1}^*) E_t \left[ \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} \mid F_{m,t-1} > F_{t-1}^* \right] \tag{A.11} \\
 &= \cancel{H(F_{t-1}^*)} \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{F_{t-1}^*} \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} \frac{dH(F_{m,t-1})}{\cancel{H(F_{t-1}^*)}} + [1 - \cancel{H(F_{t-1}^*)}] \int_{F_{t-1}^*}^{\infty} \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} \frac{dH(F_{m,t-1})}{\cancel{1 - H(F_{t-1}^*)}} \\
 &= \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{F_{t-1}^*} \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} dH(F_{m,t-1}) + \int_{F_{t-1}^*}^{\infty} \left(\frac{P_{m,t}^J}{P_t}\right)^{1-\sigma} dH(F_{m,t-1}),
 \end{aligned}$$

where  $\frac{P_{m,t}^J}{P_t}$  is given by (A.10). Plugging (A.10) into (A.11), we obtain

$$\begin{aligned}
 \left(\frac{P_t^J}{P_t}\right)^{1-\sigma} &= \Theta_1 \cdot \left(\frac{W_t}{P_t A_t}\right)^{\left(\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}\right)} \cdot \left(\frac{P_t^J}{P_t}\right)^{\left(\frac{(1-\alpha)(1-\sigma)\sigma}{\alpha+\sigma(1-\alpha)}\right)} \cdot \left(\frac{Y_t \Delta_t}{A_t}\right)^{\left(\frac{(1-\alpha)(1-\sigma)}{\alpha+\sigma(1-\alpha)}\right)} \\
 &\quad \cdot \left[ \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{F_{t-1}^*} 1 dH(F_{m,t-1}) + \int_{F_{t-1}^*}^{\infty} \left(\frac{F_{m,t-1}}{F_{t-1}^*}\right)^{-\left(\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\sigma-1}\right)} dH(F_{m,t-1}) \right], \tag{A.12}
 \end{aligned}$$

which leads to

$$\begin{aligned}
 \left(\frac{P_t^J}{P_t}\right)^{\left(\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}\right)} &= \Theta_1 \cdot \left(\frac{W_t}{P_t A_t}\right)^{\left(\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}\right)} \cdot \left(\frac{Y_t \Delta_t}{A_t}\right)^{\left(\frac{(1-\alpha)(1-\sigma)}{\alpha+\sigma(1-\alpha)}\right)} \\
 &\quad \cdot \left[ H(F_{t-1}^*) + \left(\frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)] + (\omega-1)(\sigma-1)}\right) \cdot [1 - H(F_{t-1}^*)] \right]. \tag{A.13}
 \end{aligned}$$

Rearranging equation (A.13), we finally obtain:

$$\frac{P_t^J}{P_t} = \left(\frac{W_t}{P_t A_t}\right) \cdot \left(\frac{Y_t \Delta_t}{A_t}\right)^{\frac{1-\alpha}{\alpha}} \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H(F_{t-1}^*)} \right]^{\left(\frac{\alpha+\sigma(1-\alpha)}{\alpha(\sigma-1)}\right)}. \tag{A.14}$$

## Online Appendix: For Online Publication Only

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where we define

$$\Theta_3 = \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)}{\Theta_1 \omega (\sigma - 1)} \right), \quad \Theta_4 = \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)}{\omega (\sigma - 1)} \right).$$

**Derivation of  $M_t$  and  $L_{t-1}$  in (20) and (21)**

$$\begin{aligned} M_t &= \int_0^1 \int_{v \in \Omega_{m,t}} 1 \, dv \, dm = \int_0^1 M_{m,t} \, dm = \int_0^1 M_{m,t} \cdot dH(F_{m,t-1}) \quad (\text{A.15}) \\ &= \underbrace{\text{Prob}(F_{t-1} \leq F_{t-1}^*)}_{=H(F_{t-1}^*)} \cdot 1 + \text{Prob}(F_{t-1} > F_{t-1}^*) \cdot \int_{F_{t-1}^*}^{\infty} \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{-\frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\sigma - 1}} \frac{dH(F_{m,t-1})}{1 - H(F_{t-1}^*)} \\ &= 1 - \Theta_M \cdot [1 - H(F_{t-1}^*)], \end{aligned}$$

where

$$\Theta_M = \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] + \omega(\sigma - 1)}.$$

To derive equation (17), we start from

$$\begin{aligned} \frac{L_{t-1}}{P_{t-1}} &= \frac{\int_0^1 L_{m,t-1} \, dm}{P_{t-1}} \\ &= \text{Prob}(F_{m,t-1} \leq F_{t-1}^*) \cdot \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{F_{t-1}^*} F_{m,t-1} \frac{dH(F_{m,t-1})}{H(F_{t-1}^*)} \\ &\quad + \text{Prob}(F_{m,t-1} > F_{t-1}^*) \cdot \int_{F_{t-1}^*}^{\infty} (F_{t-1}^*)^{\left(\frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\sigma - 1}\right)} \cdot F_{m,t-1}^{-\left(\frac{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)}{\sigma - 1}\right)} \frac{dH(F_{m,t-1})}{1 - H(F_{t-1}^*)} \\ &= \int_{\left(\frac{\omega-1}{\omega}\right)F_{t-1}}^{F_{t-1}^*} F_{m,t-1} \, dH(F_{m,t-1}) + \int_{F_{t-1}^*}^{\infty} (F_{t-1}^*)^{\left(\frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\sigma - 1}\right)} \cdot F_{m,t-1}^{-\left(\frac{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)}{\sigma - 1}\right)} \, dH(F_{m,t-1}), \end{aligned}$$

which leads to

$$\begin{aligned} \frac{L_{t-1}}{P_{t-1}} &= F_{t-1} - \left( \frac{\omega}{\omega - 1} \right) \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] + (\sigma - 1)(\omega - 1)} \right) \cdot F_{t-1}^* \cdot [1 - H(F_{t-1}^*)] \\ &= F_{t-1} \cdot \left[ 1 - \Theta_L \cdot [1 - H(F_{t-1}^*)]^{\left(\frac{\omega-1}{\omega}\right)} \right], \end{aligned}$$

where

$$\Theta_L = \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] + (\sigma - 1)(\omega - 1)}.$$

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**Derivation of  $N_t$  in equation (25)** Labor  $N_{mv,t}$  employed by a producing upstream firm  $(m, v)$  is given by

$$N_{mv,t} = J_{mv,t}^{\frac{1}{\alpha}} \varphi_{mv,t}^{-\frac{1}{\alpha}} = \varphi_{mv,t}^{-\frac{1}{\alpha}} \cdot \left[ \left( \frac{P_{mv,t}^J}{P_t^J} \right)^{-\sigma} \cdot J_t \right]^{\frac{1}{\alpha}} \quad (\text{A.16})$$

$$\begin{aligned} &= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \cdot \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \cdot \left( \frac{\varphi_{mv,t}}{\left( \frac{\kappa - 1}{\kappa} \right) A_t} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \\ &\cdot \left( \frac{W_t}{P_t A_t} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \cdot \left( \frac{P_t^J}{P_t} \right)^{\left( \frac{\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\left( \frac{1}{\alpha + \sigma(1 - \alpha)} \right)} \\ &= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\varphi_{mv,t}}{\left( \frac{\kappa - 1}{\kappa} \right) A_t} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \\ &\cdot \left[ \frac{\Theta_3}{1 + \Theta_4 H_{t-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}}, \end{aligned} \quad (\text{A.17})$$

where we use equation (5) in the second equality, equations (8) and (11) for the third equality, and equation (19) to obtain the fourth one. For convenience we define  $H_{t-1} \equiv H(F_{t-1}^*)$ . Now we integrate labor in (A.16) across all producing firms to obtain the aggregate labor  $N_t$ . First,

$$\begin{aligned} N_t &= \int_0^1 \int_{v \in \Omega_{m,t}} N_{mv,t} \, dv \, dm \\ &= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \left[ \left( \frac{\kappa - 1}{\kappa} \right) A_t \right]^{\left( \frac{1 - \sigma}{\alpha + \sigma(1 - \alpha)} \right)} \\ &\cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \int_0^1 \int_{v \in \Omega_{m,t}} \varphi_{mv,t}^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \, dv \, dm \\ &= \square \int_0^1 \int_{v \in \Omega_{m,t}} \varphi_{mv,t}^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \, dv \, dm, \end{aligned} \quad (\text{A.18})$$

where

$$\begin{aligned} \square &= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \left[ \left( \frac{\kappa - 1}{\kappa} \right) A_t \right]^{\left( \frac{1 - \sigma}{\alpha + \sigma(1 - \alpha)} \right)} \\ &\cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}}. \end{aligned} \quad (\text{A.19})$$

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Now, (35) leads to

$$\begin{aligned}
N_t &= \square \int_0^1 \int_{\max(\varphi_{m,t}^*, \frac{\kappa-1}{\kappa} A_t)}^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \varphi_{mv,t}^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \kappa \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^\kappa \varphi_{mv,t}^{-(\kappa+1)} d\varphi_{mv,t} dm \\
&= \square \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^\kappa \left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\kappa[\alpha + \sigma(1-\alpha)] - (\sigma-1)} \right) \\
&\quad \cdot \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\left(-\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\alpha+\sigma(1-\alpha)}\right)} \int_0^1 \max \left( \frac{\varphi_{m,t}^*}{\frac{\kappa-1}{\kappa} A_t}, 1 \right)^{\left(-\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\alpha+\sigma(1-\alpha)}\right)} dm \\
&= \square \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\kappa[\alpha + \sigma(1-\alpha)] - (\sigma-1)} \right) \int_0^1 \min \left( \left( \frac{F_{m,t-1}}{F_{t-1}^*} \right)^{-\frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{\sigma-1}}, 1 \right) dm \\
&= \square \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\kappa[\alpha + \sigma(1-\alpha)] - (\sigma-1)} \right) \\
&\quad \cdot \left[ H_{t-1} + \frac{\omega(\sigma-1)}{\kappa[\alpha + \sigma(1-\alpha)] + (\omega-1)(\sigma-1)} (1 - H_{t-1}) \right] \\
&= \square \left[ \left( \frac{\kappa-1}{\kappa} \right) A_t \right]^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\kappa[\alpha + \sigma(1-\alpha)] - (\sigma-1)} \right) \left( \frac{\omega(\sigma-1)}{\kappa[\alpha + \sigma(1-\alpha)] + (\omega-1)(\sigma-1)} \right) [1 + \Theta_4 H_{t-1}] \\
&= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma-1)\alpha} \right)^{\left(\frac{-\sigma}{\alpha+\sigma(1-\alpha)}\right)} \left( \frac{\kappa-1}{\kappa} \right)^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\kappa[\alpha + \sigma(1-\alpha)] - (\sigma-1)} \right) \\
&\quad \cdot \left( \frac{\omega(\sigma-1)}{\kappa[\alpha + \sigma(1-\alpha)] + (\omega-1)(\sigma-1)} \right) [1 + \Theta_4 H_{t-1}] \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\left(\frac{\sigma}{(\sigma-1)\alpha}\right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \\
&= \Theta_N \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \cdot (1 + \Theta_4 H_{t-1})^{\frac{\alpha+\sigma(1-\alpha)}{(1-\sigma)\alpha}},
\end{aligned}$$

where  $\Theta_N$  is defined in (26).

**Equilibrium conditions for downstream firms** Plugging equation (28) and the expression for  $Q_{t,t+l}$  into (4), we can express the resetting price in (4) in a recursive fashion as

$$\begin{aligned}
O_t &= \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right) \Theta_N^\eta \Theta_3^{\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \left( \frac{Y_t}{A_t} \right)^{\left(\frac{\eta+1}{\eta\alpha}\right)} \Delta_t^{\left(\frac{(1-\alpha)\eta+1}{\eta\alpha}\right)} (1 + \Theta_4 H_{t-1})^{\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{\eta(1-\sigma)\alpha}} \exp \{-u_{c,t}\} \\
&\quad + \beta \theta E_t [\exp \{u_{c,t+1} - u_{c,t}\} \cdot \Pi_{t+1}^\gamma \cdot O_{t+1}],
\end{aligned} \tag{A.20}$$

and

$$V_t = \left( \frac{C_t}{Y_t} \right)^{-1} + \beta \theta \cdot E_t [\exp \{u_{c,t+1} - u_{c,t}\} \cdot \Pi_{t+1}^{\gamma-1} \cdot V_{t+1}]. \tag{A.21}$$

## Online Appendix: For Online Publication Only

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We obtain

$$\frac{P_t^*}{P_t} = \frac{O_t}{V_t}. \quad (\text{A.22})$$

Due to price stickiness à la [Calvo \(1983\)](#), the aggregate price level can be recursively expressed as:

$$P_t^{1-\gamma} = (1-\theta)(P_t^*)^{1-\gamma} + \theta(P_{t-1})^{1-\gamma},$$

or alternatively as:

$$\frac{P_t^*}{P_t} = \left( \frac{1-\theta}{1-\theta \cdot \Pi_t^{\gamma-1}} \right)^{\frac{1}{\gamma-1}}. \quad (\text{A.23})$$

Plugging equation (A.22) into equation (9) and equation (A.23), we obtain

$$\frac{O_t}{V_t} = \left( \frac{1-\theta}{1-\theta \cdot \Pi_t^{\gamma-1}} \right)^{\frac{1}{\gamma-1}}, \quad \Delta_t = (1-\theta) \left( \frac{O_t}{V_t} \right)^{-\gamma} + \theta \Pi_t^\gamma \Delta_{t-1}.$$

**Equilibrium conditions for households** We can write  $F_t^*$  as a function of  $H_t$  by using the cumulative distribution function of fixed costs in (18) and (23):

$$F_t^* = [1 - H_t]^{-\frac{1}{\omega}} \left( \frac{\omega-1}{\omega} \right) \phi_f \cdot \tilde{Y} A_t \cdot \exp \{u_{f,t}\}. \quad (\text{A.24})$$

Using the above (A.24), we can rearrange equation (A.6) (i.e., equation about  $F_t^*$ ) as:

$$R_t^J = E_t \left[ \xi_{t+1} \cdot \left( \frac{P_{t+1}^J}{P_{t+1}} \right)^{\left( \frac{\sigma}{\alpha+\sigma(1-\alpha)} \right)} \left( \frac{w_{t+1}}{P_{t+1} A_{t+1}} \right)^{\left( \frac{(1-\sigma)\alpha}{\alpha+\sigma(1-\alpha)} \right)} \frac{1}{\tilde{Y}} \Pi_{t+1} G A_{t+1} \left( \frac{Y_{t+1} \Delta_{t+1}}{A_{t+1}} \right)^{\left( \frac{1}{\alpha+\sigma(1-\alpha)} \right)} \right] \\ \cdot \left( \frac{\Theta_2}{\left( \frac{\omega-1}{\omega} \right) \phi_f} \right) \left( \frac{\kappa-1}{\kappa} \right)^{\left( \frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)} \right)} [1 - H_t]^{\frac{1}{\omega}} \cdot \exp \{-u_{f,t}\}. \quad (\text{A.25})$$

Plugging (27) and (28) into the above (A.25), we obtain:

$$R_t^J = \left( \frac{\Theta_2 \Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\sigma}{(\sigma-1)\alpha}}}{\left( \frac{\omega-1}{\omega} \right) \phi_f} \right) \cdot \left( \frac{\kappa-1}{\kappa} \right)^{\left( \frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)} \right)} (1 + \Theta_4 H_t)^{\left( \frac{\alpha+\sigma(1-\alpha)+\sigma\eta}{\eta(1-\sigma)\alpha} \right)} \cdot (1 - H_t)^{\frac{1}{\omega}} \\ \cdot E_t \left[ \xi_{t+1} \Pi_{t+1} \left( \frac{C_{t+1}}{A_{t+1}} \right) \left( \frac{Y_{t+1}}{\tilde{Y}} \right) \left( \frac{Y_{t+1} \Delta_{t+1}}{A_{t+1}} \right)^{\left( \frac{\eta+1}{\eta\alpha} \right)} \cdot G A_{t+1} \cdot \exp \{-(u_{f,t} + u_{c,t+1})\} \right]. \quad (\text{A.26})$$



## Online Appendix: For Online Publication Only

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Finally, we can rearrange the Euler equation in (1), using (30) as follows:

$$\frac{1}{R_t^J} = \beta E_t \left[ \frac{\left(\frac{C_t}{Y_t}\right)}{\left(\frac{C_{t+1}}{Y_{t+1}}\right) \widetilde{GY}_{t+1} GA_{t+1} \Pi_{t+1}} \cdot \exp\{u_{c,t+1} - u_{c,t}\} \right], \quad (\text{A.27})$$

where  $\widetilde{GY}_{t+1} = \frac{Y_{t+1}}{Y_{t+1}} \frac{A_t}{A_{t+1}}$  and  $GA_{t+1} = \frac{A_{t+1}}{A_t}$ . Combining equation (A.26) and equation (A.27), we obtain

$$\begin{aligned} \exp\{u_{f,t} + u_{c,t}\} &= \beta \left( \frac{\Theta_2 \cdot \Theta_N^{\frac{1}{\eta}} \cdot \Theta_3^{\frac{\sigma}{(\sigma-1)\alpha}}}{\left(\frac{\omega-1}{\omega}\right) \phi_f} \right) \left( \frac{\kappa-1}{\kappa} \right)^{\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}} \cdot (1 + \Theta_4 H_t)^{\frac{[\alpha+\sigma(1-\alpha)]+\sigma\eta}{\eta(1-\sigma)\alpha}} \\ &\quad \cdot (1 - H_t)^{\frac{1}{\omega}} \cdot \left(\frac{C_t}{\widetilde{Y}}\right) \cdot E_t \left[ \left(\frac{Y_{t+1} \Delta_{t+1}}{A_{t+1}}\right)^{\frac{(\eta+1)}{\eta\alpha}} \right]. \end{aligned} \quad (\text{A.28})$$

**Flexible price equilibrium** Plugging (34) into (19), we obtain

$$\frac{W_t}{P_t A_t} = \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right)^{-1} \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{\alpha-1}{\alpha}} \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\frac{(\alpha+\sigma(1-\alpha))}{1-\sigma}}. \quad (\text{A.29})$$

Plugging (19) and (A.29) into (A.6) (i.e., equation about the cutoff fixed cost  $F_t^*$ ), and based on the fact that there is no price dispersion under flexible prices, i.e.,  $\Delta_t = 1$ , we obtain:

$$F_t^* = \Theta_2 \cdot \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right)^{-1} \cdot \left( \frac{\kappa-1}{\kappa} \right)^{\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}} \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_t} \right] E_t \left[ \xi_{t+1} \left( \frac{\Pi_{t+1} Y_{t+1}}{R_t^J} \right) \right]. \quad (\text{A.30})$$

By the definition of the distribution function of the fixed costs (see eq. (18)), we express:

$$[1 - H_t]^{-\frac{1}{\omega}} = \frac{F_t^*}{\left(\frac{\omega-1}{\omega}\right) F_t} = \frac{F_t^*}{\left(\frac{\omega-1}{\omega}\right) \cdot \phi_f \cdot \widetilde{Y} A_t \cdot \exp\{u_{f,t}\}}. \quad (\text{A.31})$$

Plugging equation (A.31) into equation (A.30), we obtain:

$$\begin{aligned} 1 &= \left( \frac{\beta \Theta_2}{\left(\frac{\omega-1}{\omega}\right) \cdot \phi_f} \right) \cdot \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right)^{-1} \cdot \left( \frac{\kappa-1}{\kappa} \right)^{\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}} \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_t} \right] \\ &\quad \cdot [1 - H_t]^{-\frac{1}{\omega}} \cdot E_t \left[ \left[ \frac{\widetilde{Y}}{\widetilde{Y}} \right] \left( \frac{C_t}{\frac{C_{t+1}}{Y_{t+1}}} \right) \cdot \exp\{u_{c,t+1} - (u_{f,t} + u_{c,t})\} \right]. \end{aligned} \quad (\text{A.32})$$

## Online Appendix: For Online Publication Only

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Finally, plugging (34) into (28) and based on no price dispersion under flexible prices, i.e.,  $\Delta_t = 1$ , we obtain

$$\begin{aligned} \frac{Y_t}{A_t} &= \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right)^{-\left(\frac{\eta\alpha}{(1-\alpha)\eta+1}\right)} \Theta_N^{-\left(\frac{\alpha}{(1-\alpha)\eta+1}\right)} \Theta_3^{-\frac{\eta[\alpha+\sigma(1-\alpha)]}{[(1-\alpha)\eta+1](\sigma-1)}} \cdot \left( \frac{C_t}{A_t} \right)^{-\left(\frac{\eta\alpha}{(1-\alpha)\eta+1}\right)} \\ &\quad \cdot (1 + \Theta_4 H_{t-1})^{-\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{(1-\sigma)[(1-\alpha)\eta+1]}} \cdot \exp \left\{ \left( \frac{\eta\alpha}{(1-\alpha)\eta+1} \right) \cdot u_{c,t} \right\}. \end{aligned} \quad (\text{A.33})$$

From (A.32) and (A.33), we can see that the flexible price equilibrium is money-neutral.

### A.2 Calibration of $(\kappa, \omega)$ in Section 3.1

Following intuitions of Bernard et al. (2003), we calculate the model-implied standard deviation of revenues and productivities of operating upstream firms.

#### Derivations on the cross-sectional standard deviations of sales and productivities

We start from the formula for the revenue  $r_{mv,t}$  generated by a firm  $(m, v)$  in (A.2):

$$r_{mv,t} = (1 + \zeta^J) \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1)\alpha} \right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} W_t^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} (\Gamma_t^J)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \varphi_{mv,t}^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}}, \quad (\text{A.34})$$

where

$$\varphi_{m,t}^* = \left( \frac{R_{t-1}^J P_{t-1} F_{m,t-1}}{E_{t-1} [\xi_t \cdot \Xi_t]} \right)^{\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}}. \quad (\text{A.35})$$

We can calculate the cross-sectional standard deviation of an individual firm's revenue and productivity by calculating the variance:

$$\begin{aligned} \sigma^2 (\log r_{mv,t}) &= \left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)^2 \sigma^2 (\log \varphi_{mv,t}) \\ &= \left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)^2 \sigma^2 \left( \log \frac{\varphi_{mv,t}}{\varphi_{m,t}^*} + \log \varphi_{m,t}^* \right) \\ &= \left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)^2 \left[ \sigma^2 \left( \log \frac{\varphi_{mv,t}}{\varphi_{m,t}^*} \right) + \sigma^2 (\log \varphi_{m,t}^*) \right], \end{aligned} \quad (\text{A.36})$$

where for the second line we use the property that (i)  $\phi_{mv,t} | \phi_{mv,t} \geq \phi_{m,t}^*$  follows a Pareto distribution; (ii) distributions of productivities and fixed costs are independent of each other.

## Online Appendix: For Online Publication Only

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Therefore,

$$\begin{aligned}\sigma^2(\log r_{mv,t}) &= \left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)^2 \left[ \sigma^2 \left( \log \frac{\varphi_{mv,t}}{\varphi_{m,t}^*} \right) + \left(\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}\right)^2 \sigma^2(\log F_{m,t-1}) \right] \\ &= \left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)^2 \left[ \frac{1}{\kappa^2} + \left(\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}\right)^2 \frac{1}{\omega^2} \right],\end{aligned}$$

which implies

$$\sigma(\log r_{mv,t}) = \frac{\sigma-1}{\alpha+\sigma(1-\alpha)} \sqrt{\frac{1}{\kappa^2} + \left(\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}\right)^2 \frac{1}{\omega^2}},$$

and

$$\sigma(\log \varphi_{mv,t}) = \sqrt{\frac{1}{\kappa^2} + \left(\frac{\alpha+\sigma(1-\alpha)}{\sigma-1}\right)^2 \frac{1}{\omega^2}}.$$

**Revenue heterogeneity in our model** With  $\kappa = \omega = 3.4$ , our model predicts the standard deviation of upstream firms' revenues to be 0.44. The residual variability in [Bernard et al. \(2003\)](#) stem from some factors we do not account for, such as taste heterogeneity or different demand weights for product types. Additionally, their estimates are based on U.S. manufacturing plants, whereas our framework focuses on upstream firms.

Regarding productivity variability, the standard deviation of log productivity for operating upstream firms in our model becomes 0.4 when  $\kappa = \omega = 3.4$ . According to [Bernard et al. \(2003\)](#), their model-generated standard deviation of log value-added per worker is 0.35, while the empirical figure stands at 0.75.<sup>1</sup> Given the potential for measurement errors, our calibration is closely aligned with their model-generated moment and falls within a plausible range.

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<sup>1</sup>[Bernard et al. \(2003\)](#) note that some degree of under-prediction could result from measurement errors in Census data.

## Online Appendix: For Online Publication Only

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### A.3 Detailed Derivation in Section 4.2

**Intensive vs. extensive margin labor adjustments: derivation of (37)** From (35), (A.19), and (A.20), we know that the aggregate labor  $N_t$  can be written as

$$\begin{aligned}
 N_t &= \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)} \right) \\
 &\quad \cdot \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \left[ H_{t-1} + \frac{\omega(\sigma - 1)}{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)} (1 - H_{t-1}) \right] \\
 &= \Theta_{DN} \left[ \frac{\Theta_3}{1 + \Theta_4 \cdot H_{t-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \underbrace{\left[ H_{t-1} + \frac{\omega(\sigma - 1)}{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)} (1 - H_{t-1}) \right]}_{\equiv SN_t^I},
 \end{aligned}$$

where

$$\Theta_{DN} \equiv \left( \frac{(1 + \zeta^J)^{-1} \sigma}{(\sigma - 1) \alpha} \right)^{\left( \frac{-\sigma}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{\sigma - 1}{\alpha + \sigma(1 - \alpha)} \right)} \left( \frac{\kappa[\alpha + \sigma(1 - \alpha)]}{\kappa[\alpha + \sigma(1 - \alpha)] - (\sigma - 1)} \right). \quad (\text{A.37})$$

From (A.37), we obtain for  $\forall \iota$

$$\frac{N_{t+\iota} - N_t}{N_t} = \underbrace{\left[ \frac{1 + \Theta_4 \cdot H_{t-1}}{1 + \Theta_4 \cdot H_{t+\iota-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_{t+\iota} \Delta_{t+\iota} / A_{t+\iota}}{Y_t \Delta_t / A_t} \right)^{\frac{1}{\alpha}} - 1}_{\equiv g_{t,t+\iota}^{\text{Density}}} \quad (\text{A.38})$$

$$+ \left\{ 1 + \underbrace{\left[ \frac{1 + \Theta_4 \cdot H_{t-1}}{1 + \Theta_4 \cdot H_{t+\iota-1}} \right]^{\left( \frac{\sigma}{(\sigma - 1) \alpha} \right)} \left( \frac{Y_{t+\iota} \Delta_{t+\iota} / A_{t+\iota}}{Y_t \Delta_t / A_t} \right)^{\frac{1}{\alpha}} - 1}_{\equiv g_{t,t+\iota}^{\text{Density}}} \right\} \cdot \underbrace{\frac{SN_{t,t+\iota}^E}{SN_t^I}}_{\equiv g_{t,t+\iota}^{\text{Entry}}}. \quad (\text{A.39})$$

Therefore, by (36) and the definition of the decomposition in (37), we obtain (38):

$$g_{t,t+\iota}^{\text{Entry}} \equiv \frac{SN_{t,t+\iota}^E}{SN_t^I} = \frac{(H_{t+\iota-1} - H_{t-1}) + \frac{\omega(\sigma - 1)}{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)} (H_{t-1} - H_{t+\iota-1})}{H_{t-1} + \frac{\omega(\sigma - 1)}{\kappa[\alpha + \sigma(1 - \alpha)] + (\omega - 1)(\sigma - 1)} (1 - H_{t-1})}. \quad (\text{A.40})$$

## B Summary of Equilibrium Conditions

### B.1 Sticky Price Equilibrium (i.e., Original Model)

$$\begin{aligned}
 \exp \{u_{f,t} + u_{c,t}\} &= \beta \left( \frac{\Theta_2 \cdot \Theta_N^{\frac{1}{\eta}} \cdot \Theta_3^{\frac{\sigma}{(\sigma-1)\alpha}}}{\left(\frac{\omega-1}{\omega}\right) \phi_f} \right) \left( \frac{\kappa-1}{\kappa} \right)^{\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}} \cdot (1 + \Theta_4 H_t)^{\frac{(\alpha+\sigma(1-\alpha)+\sigma\eta)}{\eta(1-\sigma)\alpha}} \\
 &\quad \cdot (1 - H_t)^{\frac{1}{\omega}} \cdot \left( \frac{\tilde{C}_t}{\tilde{Y}_t} \right) \cdot E_t \left[ \left( \tilde{Y}_{t+1} \Delta_{t+1} \right)^{\frac{\eta+1}{\eta\alpha}} \right] \\
 \frac{1}{R_t^J} &= \beta E_t \left[ \frac{\tilde{C}_t}{\tilde{C}_{t+1} G A_{t+1} \Pi_{t+1}} \cdot \exp \{u_{c,t+1} - u_{c,t}\} \right] \\
 \frac{\tilde{C}_t}{\tilde{Y}_t} &= 1 - \phi_g \cdot \exp \{u_{g,t}\} - \phi_f \cdot \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right)^{-1} \cdot \left[ 1 - \Theta_L \cdot [1 - H_t]^{\left(\frac{\omega-1}{\omega}\right)} \right] \cdot \exp \{u_{f,t}\} \\
 O_t &= \left( \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right) \Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \tilde{Y}_t^{\frac{(\eta+1)}{\eta\alpha}} \Delta_t^{\frac{(1-\alpha)\eta+1}{\eta\alpha}} (1 + \Theta_4 H_{t-1})^{\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{\eta(1-\sigma)\alpha}} \exp \{-u_{c,t}\} \\
 &\quad + \beta \theta E_t \left[ \exp \{u_{c,t+1} - u_{c,t}\} \cdot \Pi_{t+1}^\gamma \cdot O_{t+1} \right] \\
 V_t &= \left( \frac{\tilde{C}_t}{\tilde{Y}_t} \right)^{-1} + \beta \theta \cdot E_t \left[ \exp \{u_{c,t+1} - u_{c,t}\} \cdot \Pi_{t+1}^{\gamma-1} \cdot V_{t+1} \right] \\
 \frac{O_t}{V_t} &= \left( \frac{1 - \theta}{1 - \theta \cdot \Pi_t^{\gamma-1}} \right)^{\frac{1}{\gamma-1}} \\
 \Delta_t &= (1 - \theta) \left( \frac{O_t}{V_t} \right)^{-\gamma} + \theta \Pi_t^\gamma \Delta_{t-1} \\
 R_t^J &= R^J \cdot \left( \frac{\Pi_t}{\Pi} \right)^{\tau_\pi} \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right)^{\tau_y} \cdot \exp \{\varepsilon_{r,t}\}, \quad \varepsilon_{r,t} \sim N(0, \sigma_r^2) \\
 \tilde{F}_t^* &\equiv \frac{F_t^*}{A_t} = [1 - H_t]^{-\frac{1}{\omega}} \left( \frac{\omega-1}{\omega} \right) \phi_f \cdot \tilde{Y} \cdot \exp \{u_{f,t}\} \\
 R_t^{J,*} &= \left( \frac{\omega}{\omega+1} \right) \cdot (1 - H_t)^{-\frac{1}{\omega}} \cdot R_t^B \\
 N_t &= \Theta_N \cdot \left( \tilde{Y}_t \Delta_t \right)^{\frac{1}{\alpha}} \cdot (1 + \Theta_4 H_{t-1})^{\frac{\alpha+\sigma(1-\alpha)}{(1-\sigma)\alpha}} \\
 g_{t,t+1}^{Density} &= \left[ \frac{1 + \Theta_4 \cdot H_{t-1}}{1 + \Theta_4 \cdot H_t} \right]^{\frac{\sigma}{(\sigma-1)\alpha}} \left( \frac{\tilde{Y}_{t+1} \Delta_{t+1}}{\tilde{Y}_t \Delta_t} \right)^{\frac{1}{\alpha}} - 1 \\
 g_{t,t+1}^{Entry} &= \frac{(H_t - H_{t-1}) + \frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)]+(\omega-1)(\sigma-1)} (H_{t-1} - H_t)}{H_{t-1} + \frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)]+(\omega-1)(\sigma-1)} (1 - H_{t-1})} \\
 \frac{W_t}{P_t A_t} &= \Theta_N^{\frac{1}{\eta}} \left( \tilde{C}_t \right) \left( \tilde{Y}_t \Delta_t \right)^{\frac{1}{\eta\alpha}} (1 + \Theta_4 H_{t-1})^{\frac{\alpha+\sigma(1-\alpha)}{\eta(1-\sigma)\alpha}} \cdot \exp \{-u_{c,t}\}
 \end{aligned}$$

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$$\begin{aligned} \frac{P_t^J}{P_t} &= \Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \left(\tilde{C}_t\right) \left(\tilde{Y}_t \Delta_t\right)^{\left(\frac{(1-\alpha)\eta+1}{\eta\alpha}\right)} \left(1 + \Theta_4 H_{t-1}\right)^{\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{\eta(1-\sigma)\alpha}} \cdot \exp\{-u_{c,t}\} \\ M_{t+1} &= 1 - \Theta_M \cdot [1 - H_t] \\ \frac{L_t/P_t}{\tilde{Y}_t} &= \phi_f \cdot \left[1 - \Theta_L \cdot [1 - H_t]^{\left(\frac{\omega-1}{\omega}\right)}\right] \cdot \exp\{u_{f,t}\} \\ GA_t &= (1 + \mu) \cdot \exp\{u_{a,t}\} \end{aligned}$$

### Shock processes:

$$\begin{aligned} u_{a,t} &= \rho_a \cdot u_{a,t-1} + \varepsilon_{a,t}, \quad \varepsilon_{a,t} \sim N(0, \sigma_a^2) \\ u_{c,t} &= \rho_c \cdot u_{c,t-1} + \varepsilon_{c,t}, \quad \varepsilon_{c,t} \sim N(0, \sigma_c^2) \\ u_{g,t} &= \rho_g \cdot u_{g,t-1} + \varepsilon_{g,t}, \quad \varepsilon_{g,t} \sim N(0, \sigma_g^2) \\ u_{f,t} &= \rho_f \cdot u_{f,t-1} + \varepsilon_{f,t}, \quad \varepsilon_{f,t} \sim N(0, \sigma_f^2) \end{aligned}$$

### Parameters:

$$\begin{aligned} \Theta_1 &= \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{\frac{\alpha(1-\sigma)}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa-1}{\kappa}\right)^{\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)] - (\sigma-1)}\right) \\ \Theta_2 &= \frac{\alpha+\sigma(1-\alpha)}{\alpha(\sigma-1)} \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{-\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left(\frac{\kappa-1}{\kappa}\right)^{\frac{\alpha(\sigma-1)}{\alpha+\sigma(1-\alpha)}} \\ \Theta_3 &= \left(\frac{\kappa[\alpha+\sigma(1-\alpha)] + (\omega-1)(\sigma-1)}{\Theta_1\omega(\sigma-1)}\right) \\ \Theta_4 &= \left(\frac{\kappa[\alpha+\sigma(1-\alpha)] - (\sigma-1)}{\omega(\sigma-1)}\right) \\ \Theta_N &= \left(\frac{(1+\zeta^J)^{-1}\sigma}{(\sigma-1)\alpha}\right)^{\left(\frac{-\sigma}{\alpha+\sigma(1-\alpha)}\right)} \left(\frac{\kappa-1}{\kappa}\right)^{\left(\frac{\sigma-1}{\alpha+\sigma(1-\alpha)}\right)} \left(\frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)] - (\sigma-1)}\right) \\ &\quad \cdot \left(\frac{\omega(\sigma-1)}{\kappa[\alpha+\sigma(1-\alpha)] + (\omega-1)(\sigma-1)}\right) \Theta_3^{\left(\frac{\sigma}{\alpha(\sigma-1)}\right)} > 0 \\ \Theta_M &= \frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)] + \omega(\sigma-1)} \\ \Theta_L &= \frac{\kappa[\alpha+\sigma(1-\alpha)]}{\kappa[\alpha+\sigma(1-\alpha)] + (\sigma-1)(\omega-1)} \end{aligned}$$

## B.2 Flexible Price Equilibrium

$$\begin{aligned}
 1 &= \left( \frac{\beta \Theta_2}{\left(\frac{\omega-1}{\omega}\right) \cdot \phi_f} \right) \cdot \left( \frac{(1+\zeta^T)^{-1} \gamma}{\gamma-1} \right)^{-1} \cdot \left( \frac{\kappa-1}{\kappa} \right)^{\left(\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}\right)} \cdot \left[ \frac{\Theta_3}{1+\Theta_4 \cdot H_t} \right] [1-H_t]^{\frac{1}{\omega}} \\
 &\quad \cdot E_t \left[ \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right) \left( \frac{\tilde{C}_t / \tilde{Y}_t}{\tilde{C}_{t+1} / \tilde{Y}_{t+1}} \right) \cdot \exp \{u_{c,t+1} - (u_{f,t} + u_{c,t})\} \right] \\
 \tilde{Y}_t &= \left( \frac{(1+\zeta^T)^{-1} \gamma}{\gamma-1} \right)^{-\left(\frac{\eta \alpha}{(1-\alpha)\eta+1}\right)} \Theta_N^{-\left(\frac{\alpha}{(1-\alpha)\eta+1}\right)} \Theta_3^{-\frac{\eta[\alpha+\sigma(1-\alpha)]}{[(1-\alpha)\eta+1](\sigma-1)}} \cdot \tilde{C}_t^{-\left(\frac{\eta \alpha}{(1-\alpha)\eta+1}\right)} \\
 &\quad \cdot (1+\Theta_4 H_{t-1})^{-\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{(1-\sigma)[(1-\alpha)\eta+1]}} \cdot \exp \left\{ \left( \frac{\eta \alpha}{(1-\alpha)\eta+1} \right) \cdot u_{c,t} \right\} \\
 \frac{\tilde{C}_t}{\tilde{Y}_t} &= 1 - \phi_g \cdot \exp \{u_{g,t}\} - \phi_f \cdot \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right)^{-1} \cdot [1 - \Theta_L \cdot [1 - H_t]^{\left(\frac{\omega-1}{\omega}\right)}] \cdot \exp \{u_{f,t}\} \\
 \tilde{F}_t^* &\equiv \frac{F_t^*}{A_t} = [1 - H_t]^{-\frac{1}{\omega}} \left( \frac{\omega-1}{\omega} \right) \phi_f \cdot \tilde{Y} \cdot \exp \{u_{f,t}\} \\
 R_t^J &= R^J \cdot \left( \frac{\Pi_t}{\Pi} \right)^{\tau_\pi} \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right)^{\tau_y} \cdot \exp \{\varepsilon_{r,t}\} \\
 R_t^{J,*} &= \left( \frac{\omega}{\omega+1} \right) \cdot (1 - H_t)^{-\frac{1}{\omega}} \cdot R_t^B
 \end{aligned}$$

**Shock processes:**

$$\begin{aligned}
 GA_t &= (1 + \mu) \cdot \exp \{u_{a,t}\} \\
 u_{a,t} &= \rho_a \cdot u_{a,t-1} + \varepsilon_{a,t} \\
 u_{c,t} &= \rho_c \cdot u_{c,t-1} + \varepsilon_{c,t} \\
 u_{g,t} &= \rho_g \cdot u_{g,t-1} + \varepsilon_{g,t} \\
 u_{f,t} &= \rho_f \cdot u_{f,t-1} + \varepsilon_{f,t} \\
 \varepsilon_{c,t} &\sim N(0, \sigma_c^2) \\
 \varepsilon_{a,t} &\sim N(0, \sigma_a^2) \\
 \varepsilon_{g,t} &\sim N(0, \sigma_g^2) \\
 \varepsilon_{f,t} &\sim N(0, \sigma_f^2) \\
 \varepsilon_{r,t} &\sim N(0, \sigma_r^2)
 \end{aligned}$$

### B.3 Steady State Conditions

$$\begin{aligned}
 R^B &= \beta^{-1}(1 + \mu)\Pi \\
 \Delta &= \left( \frac{1 - \theta}{1 - \theta\Pi\gamma} \right) \left( \frac{1 - \theta\Pi\gamma^{-1}}{1 - \theta} \right)^{\left(\frac{\gamma}{\gamma-1}\right)} \\
 \frac{\Theta_3 \cdot [1 - H]^{\frac{1}{\omega}}}{1 + \Theta_4 \cdot H} &= \left( \frac{\kappa - 1}{\kappa} \right)^{\left(\frac{(1-\sigma)(1-\alpha)}{\alpha+\sigma(1-\alpha)}\right)} \left[ \frac{(1 + \zeta^T)^{-1}\gamma}{\gamma - 1} \right] \left[ \frac{1 - \theta\Pi\gamma}{1 - \theta\Pi\gamma^{-1}} \right] \left[ \frac{1 - \beta\theta\Pi\gamma^{-1}}{1 - \beta\theta\Pi\gamma} \right] \left( \frac{\omega-1}{\beta \cdot \Theta_2} \right) \\
 \tilde{Y} &= \frac{\left( \frac{\beta\Theta_2\Theta_N^{\frac{1}{\eta}}\Theta_3^{\frac{\sigma}{(\sigma-1)\alpha}}}{\left(\frac{\omega-1}{\omega}\right)\phi_f} \right)^{-\left(\frac{\eta\alpha}{\eta+1}\right)} \left( \frac{\kappa-1}{\kappa} \right)^{\left(\frac{-\eta\alpha(\sigma-1)(1-\alpha)}{[\alpha+\sigma(1-\alpha)](\eta+1)}\right)} (1 + \Theta_4 H)^{-\frac{[\alpha+\sigma(1-\alpha)]+\sigma\eta}{(\eta+1)(1-\sigma)}} (1 - H)^{-\frac{\eta\alpha}{\omega(\eta+1)}}}{\Delta \cdot \left[ 1 - \phi_g - \phi_f \cdot \left[ 1 - \Theta_L \cdot [1 - H]^{\left(\frac{\omega-1}{\omega}\right)} \right] \right]^{\left(\frac{\eta\alpha}{\eta+1}\right)}} \\
 \tilde{C} &= \left[ 1 - \phi_g - \phi_f \cdot \left[ 1 - \Theta_L \cdot [1 - H]^{\left(\frac{\omega-1}{\omega}\right)} \right] \right] \cdot \tilde{Y} \\
 M &= 1 - \Theta_M \cdot [1 - H] \\
 \tilde{F}^* &= [1 - H]^{-\frac{1}{\omega}} \left( \frac{\omega - 1}{\omega} \right) \phi_f \cdot \tilde{Y} \\
 R^{J,*} &= \left( \frac{\omega}{\omega + 1} \right) \cdot (1 - H)^{-\frac{1}{\omega}} \cdot \beta^{-1}(1 + \mu)\Pi \\
 \frac{R^{J,*}}{R^B} &= \left( \frac{\omega}{\omega + 1} \right) \cdot (1 - H)^{-\frac{1}{\omega}} \\
 N &= \Theta_N \cdot \tilde{Y}^{\frac{1}{\alpha}} \cdot \Delta^{\frac{1}{\alpha}} \cdot (1 + \Theta_4 H)^{\frac{\alpha+\sigma(1-\alpha)}{\eta(1-\sigma)\alpha}} \\
 \frac{W}{PA} &= \Theta_N^{\frac{1}{\eta}} \tilde{C} \tilde{Y}^{\frac{1}{\eta\alpha}} \Delta^{\frac{1}{\eta\alpha}} (1 + \Theta_4 H)^{\frac{\alpha+\sigma(1-\alpha)}{\eta(1-\sigma)\alpha}} \\
 \frac{P_t^J}{P_t} &= \Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \tilde{C} (\tilde{Y} \Delta)^{\left(\frac{(1-\alpha)\eta+1}{\eta\alpha}\right)} (1 + \Theta_4 H)^{\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{\eta(1-\sigma)\alpha}} \\
 O &= \frac{(1 + \zeta^T)^{-1}\gamma}{\gamma - 1} \cdot \frac{\Theta_N^{\frac{1}{\eta}} \Theta_3^{\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \tilde{Y}^{\left(\frac{\eta+1}{\eta\alpha}\right)} \Delta^{\frac{(1-\alpha)\eta+1}{\eta\alpha}} (1 + \Theta_4 H)^{\frac{(1+\eta)[\alpha+\sigma(1-\alpha)]}{\eta(1-\sigma)\alpha}}}{1 - \beta\theta\Pi\gamma} \\
 V &= \frac{\left( \frac{\tilde{C}}{\tilde{Y}} \right)^{-1}}{1 - \beta\theta\Pi\gamma^{-1}} \\
 \frac{L/P}{\tilde{Y}} &= \phi_f \left[ 1 - \Theta_L (1 - H)^{\frac{\omega-1}{\omega}} \right]
 \end{aligned}$$

## C Estimation of Satiation Measure $H_t$ and the Policy Room

Since the satiation measure  $H_t$  and the policy room  $\frac{R_t^B}{R_t^{J,*}}$  are not directly observable, we propose two methods to infer these unobservable measures from the data. By estimating the  $H_t$  series from observable data, the policy room measure can be straightforwardly derived,



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given the close relationship between the two.

### C.1 Version 1: Estimation of Satiation Measure $H_t$

First, we can divide equation (25) by its steady-state expression to obtain:

$$\frac{N_t}{N} = \left( \frac{\tilde{Y}_t}{\tilde{Y}} \cdot \frac{\Delta_t}{\Delta} \right)^{\frac{1}{\alpha}} \cdot \left( \frac{1 + \Theta_4 H_{t-1}}{1 + \Theta_4 H} \right)^{\frac{\alpha + \sigma(1-\alpha)}{(1-\sigma)\alpha}}.$$

Taking logs, we obtain:

$$\hat{n}_t = \frac{1}{\alpha} \left( \hat{y}_t + \widehat{\log(\Delta_t)} \right) + \left( \frac{\alpha + \sigma(1-\alpha)}{(1-\sigma)\alpha} \right) \log(1 + \widehat{\Theta_4 H_{t-1}}).$$

We now proceed by replacing  $\hat{n}_t$ ,  $\hat{y}_t$  and  $\widehat{\log(\Delta_t)}$  with the HP-filtered empirical estimates based on data on employment, real GDP, and price dispersion, respectively.<sup>2</sup> Once we have these empirical estimates, we plug them into the previous equation, through which we obtain an estimate of  $\log(1 + \widehat{\Theta_4 H_{t-1}})$  as:

$$\text{Estimate} \left( \log(1 + \widehat{\Theta_4 H_{t-1}}) \right) = \left( \frac{(1-\sigma)\alpha}{\alpha + \sigma(1-\alpha)} \right) \left[ \hat{n}_t - \frac{1}{\alpha} \left( \hat{y}_t + \widehat{\log(\Delta_t)} \right) \right],$$

which leads to

$$\text{Estimate}(H_{t-1}) = \frac{1}{\Theta_4} \cdot \left[ \exp \left\{ \text{Estimate} \left( \log(1 + \widehat{\Theta_4 H_{t-1}}) \right) + \log(1 + \Theta_4 H) \right\} - 1 \right].$$

For the data on  $N_t$ , we use (i) the number of employees, (ii) average weekly hours, (iii) index of average weekly hours, all from CES National Databases in the Bureau of Labor Statistics (BLS). Figure C.1 depicts  $H_t$  series recovered with this method. We can observe that  $H_t$  is strongly procyclical.

### C.2 Version 2: Estimation of Satiation Measure $H_t$

Instead of relying on employment data, we directly use the number of establishments from the Quarterly Census of Employment and Wages (QCEW) as a proxy for fluctuations in

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<sup>2</sup>Notice that we HP-filter the logs of each variable, not their levels.

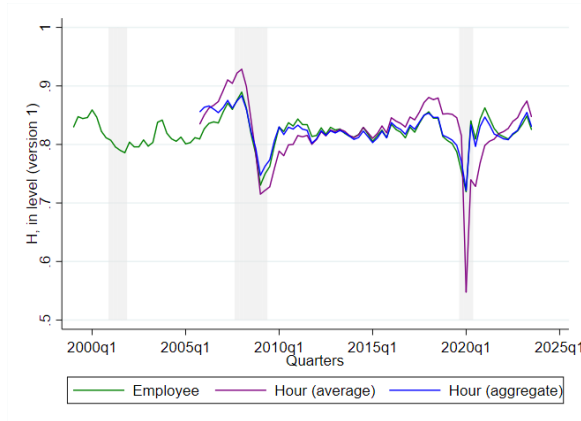


Figure C.1: Satiating measure  $H_t$ , Version 1

*Notes:* The three series are estimated based on three sources of information on the employment  $N$ . Employee: number of employees. Hour (average): average weekly hour. Hour (aggregate): aggregate weekly hour, in thousands. All from BLS CES National Databases.

firm participation, denoted as  $M_{t+1}$ , at business cycle frequencies.<sup>3</sup> Dividing equation (15) by its steady state equivalent expression, we obtain:

$$\frac{M_{t+1}}{M} = \frac{1 - \Theta_M \cdot [1 - H_t]}{1 - \Theta_M \cdot [1 - H]} .$$

Taking logs on both sides, with  $m_t \equiv \log M_t$ :

$$\hat{m}_{t+1} = \log (1 - \widehat{\Theta_M \cdot [1 - H_t]}) ,$$

so we can back out  $H_t$  as:

$$H_t = -\frac{1}{\Theta_M} \cdot [1 - \Theta_M - \exp \{ \hat{m}_{t+1} + \log (1 - \Theta_M \cdot [1 - H]) \}] ,$$

where  $\hat{m}_{t+1}$  is the HP-filtered data of the log of firm participation. The spikiness of estimated  $H$  under Version 2 comes from the spikiness of the number of establishments data.

**Comparison** Figure C.3 compares the  $H_t$  series recovered by Version 1 (based on the number of employees) and Version 2 (based on the number of establishments from the

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<sup>3</sup>As shown in Figure C.2, we also derive the  $H_t$  series using various measures of firm participation, including the number of establishments from the Business Employment Dynamics (BED) of the BLS.

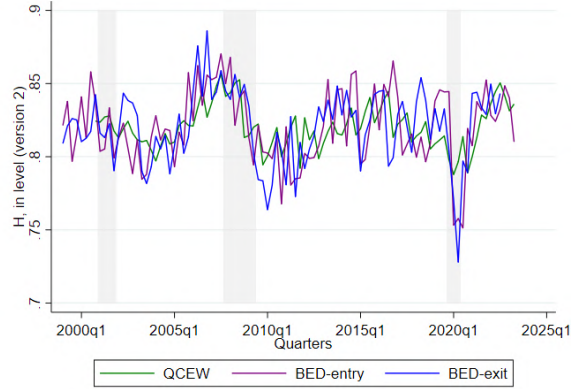


Figure C.2: Satiation measure  $H_t$ , Version 2.

*Notes:* The time series are estimated based on three sources of information on the operating firms  $M$ . The green line is based on the number of establishments in the QCEW database. The purple (blue) line is the number of establishments based on firm entry (exit) information in BED. The equation is:

$$\text{Number of establishments} = \frac{\text{number of establishments with employment gains (loss)}}{\text{percentage of establishments with employment gains (loss)}}.$$

QCEW database). Version 1 generates a more volatile  $H_t$  series. As our model lacks physical capital, using the labor demand formula (i.e., equation (25)) to recover the satiation measure  $H_t$  might overemphasize its role in driving labor demand fluctuations, leading to more volatile  $H_t$  time series.

In our baseline empirical specification in Section 5, we use Version 2, based on the number of establishments from the QCEW database, as the benchmark. Results based on Version 1, which uses the total number of employees to measure the  $H_t$  series, are provided in Appendix E as additional robustness checks.

### C.3 Estimation of the Fixed Cost Process: $\phi_f$ , $\rho_f$ , and $\sigma_f$

We start from:

$$\left( \frac{L_t}{P_t Y_t} \right) \left( \frac{\tilde{Y}_t}{\tilde{Y}} \right) = \phi_f \cdot \left[ 1 - \Theta_L \cdot (1 - H_t)^{\frac{\omega-1}{\omega}} \right] \cdot \exp \left( u_t^f \right),$$

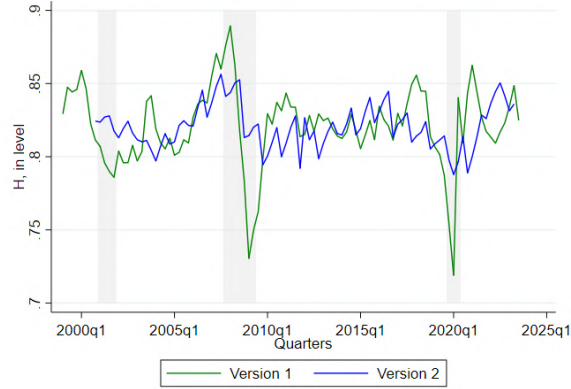


Figure C.3: Satiation Measure  $H_t$ , Version 1 vs. Version 2.

*Notes:* The  $H$  time series within each panel are estimated using two different methods. The green line is based on Version 1 with  $N$  measured by the total number of employees. The blue line is based on Version 2 with  $M$  measured by the number of establishments from the QCEW database.

where the left-hand side is written in the current (private) loan-to-GDP ratio and the output gap. Taking logs and rearranging, we obtain:

$$u_t^f = \log\left(\frac{L_t}{P_t Y_t}\right) + \tilde{y}_t - \log(\phi_f) - \log\left[1 - \Theta_L \cdot (1 - H_t)^{\frac{\omega-1}{\omega}}\right]. \quad (\text{C.1})$$

Once we have an estimate for  $H_t$  series and  $\phi_f$ , we back out  $u_t^f$  from (C.1) and estimate the AR(1) process parameters  $\rho_f$  and  $\sigma_f$  as follows:

$$u_t^f = \rho_f \cdot u_{t-1}^f + \varepsilon_t^f, \quad \varepsilon_t^f \sim N(0, \sigma_f^2). \quad (\text{C.2})$$

Appendix C.3.1 explains in detail how we obtain  $\phi_f$ ,  $\rho_f$ , and  $\sigma_f$  based on equation (C.1) and equation (C.2).

Figure C.4 plots the time series of nominal private debt to nominal GDP ratio measured by debt securities and loans to GDP ratio for nonfinancial corporate business, which we use as a proxy for  $\frac{L_t}{P_t Y_t}$ .<sup>4</sup>

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<sup>4</sup>Data source: <https://fred.stlouisfed.org/graph/?g=VLW>.

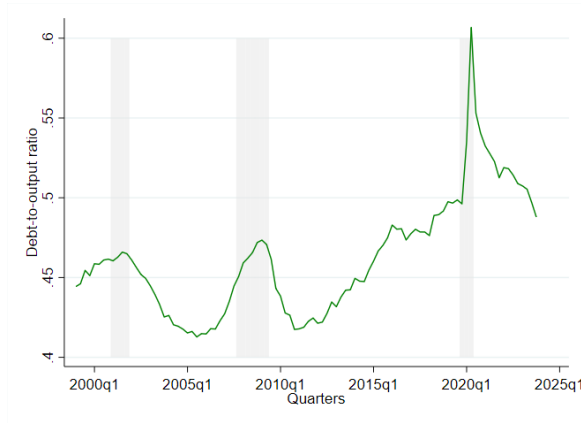


Figure C.4: Private Loan-to-output ratio.

### C.3.1 Detailed Estimation Procedure

**Step 1** Given the calibration in Table 1, we solve for  $\phi_f$  and  $H$  from the following two steady state expressions:

$$\frac{\Theta_3 \cdot [1 - H]^{\frac{1}{\omega}}}{1 + \Theta_4 \cdot H} = \left( \frac{\kappa - 1}{\kappa} \right)^{\left( \frac{(1-\sigma)(1-\alpha)}{\alpha + \sigma(1-\alpha)} \right)} \left[ \frac{(1 + \zeta^T)^{-1} \gamma}{\gamma - 1} \right] \left[ \frac{1 - \theta \Pi^\gamma}{1 - \theta \Pi^{\gamma-1}} \right] \left[ \frac{1 - \beta \theta \Pi^{\gamma-1}}{1 - \beta \theta \Pi^\gamma} \right] \left( \frac{\left( \frac{\omega-1}{\omega} \right) \phi_f}{\beta \cdot \Theta_2} \right),$$

and

$$\frac{L}{P\bar{Y}} = \phi_f \left[ 1 - \Theta_L (1 - H)^{\frac{\omega-1}{\omega}} \right],$$

where we calibrate the steady state loan-to-output ratio to its sample average:

$$\frac{L}{P\bar{Y}} = \text{Average} \left\{ \frac{L_t}{P_t Y_t} \right\},$$

and obtain a system of two equations in the unknown  $\phi_f$  and  $H$  values, which we find numerically.

**Step 2** Compute  $H_t$  (either from Version 1 or Version 2) using the above calculated  $\phi_f$ .

**Step 3** Back out  $w_t^f$  from equation (C.1) using the estimated series for  $H_t$  and the parameter estimate for  $\phi_f$ . Then, estimate the parameters  $\rho_f$  and  $\sigma_f$  in equation (C.2) via OLS regression and the volatility of the regression residuals, respectively.

### C.4 Estimation of the Policy Room $\frac{R_t^B}{R_t^{J,*}}$

As policy room  $\frac{R_t^B}{R_t^{J,*}}$  is not observable, we use the estimated  $H_t$  series (either from Version 1 or Version 2) in recovering the  $\frac{R_t^B}{R_t^{J,*}}$  series. Rearranging equation (31), we obtain:

$$\frac{R_t^B}{R_t^{J,*}} = \left( \frac{\omega + 1}{\omega} \right) \cdot (1 - H_t)^{\frac{1}{\omega}},$$

which we can estimate by plugging in the values of estimated  $H_t$ . Dividing the previous equation by its steady-state value, we obtain:

$$\left( \frac{R_t^B}{R_t^{J,*}} \right) \div \left( \frac{R^B}{R^{J,*}} \right) = \left( \frac{1 - H_t}{1 - H} \right)^{\frac{1}{\omega}},$$

which in log-deviations becomes:

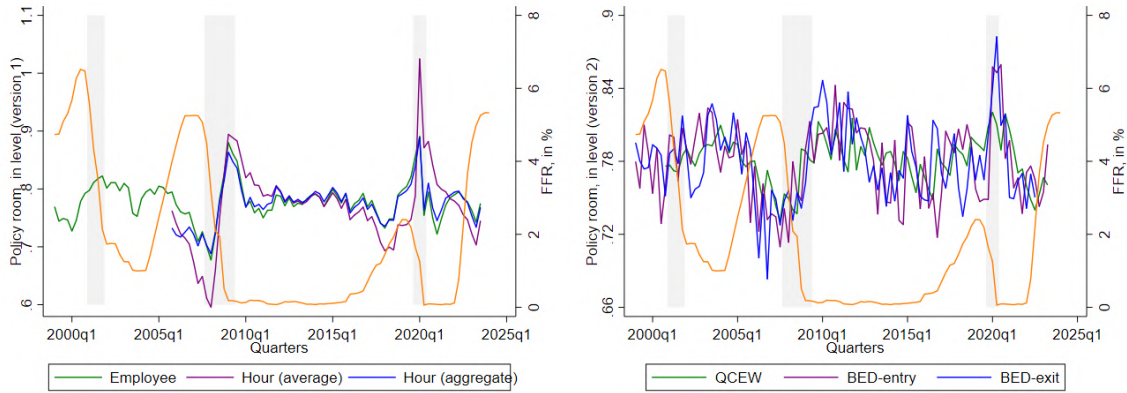
$$\widehat{r_t^B} - \widehat{r_t^{J,*}} = \frac{1}{\omega} \cdot \log(\widehat{1 - H_t}), \quad (\text{C.3})$$

which is the expression that we use as a proxy for the policy room in our empirical analysis. Figure C.5 depicts the policy room series based on Version 1 and Version 2, respectively. We observe that the policy room tends to spike during recessions where the policy rate tends to be low and around zero (i.e., zero lower bound).

## D Additional Tables and Figures

### D.1 Section 3.2

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(a) Policy room: Version 1

(b) Policy room: Version 2

Figure C.5: Policy room, Version 1 and Version 2.

*Notes:* For Version 1, the three series are estimated based on three sources of information on the employment  $N$ . Employee: number of employees. Hour (average): average weekly hour. Hour (aggregate): aggregate weekly hour, in thousands. The yellow solid line is the federal funds rates. For Version 2, the three time series are estimated based on three sources of information on the operating firms  $M$ . The green line is based on the number of establishments in QCEW database. The purple (blue) line is the number of establishments based on firm entry (exit) information in BED. The yellow line is the federal funds rates. The equation is:

$$\text{Number of establishments} = \frac{\text{number of establishments with employment gains (loss)}}{\text{percentage of establishments with employment gains (loss)}}$$

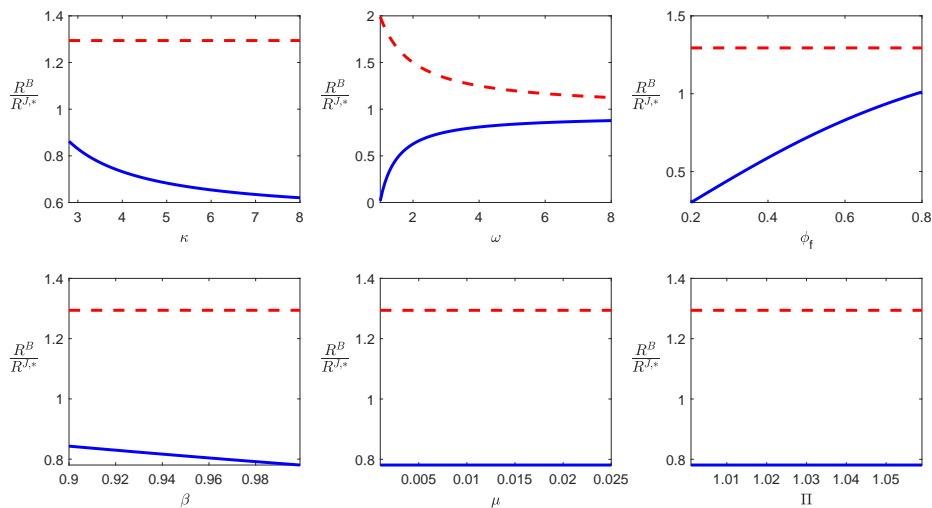


Figure D.6: Comparative Statics,  $M$ .

*Notes:* This figure displays how variations in other structural parameters affect the relation between  $M$  and the structural parameters.

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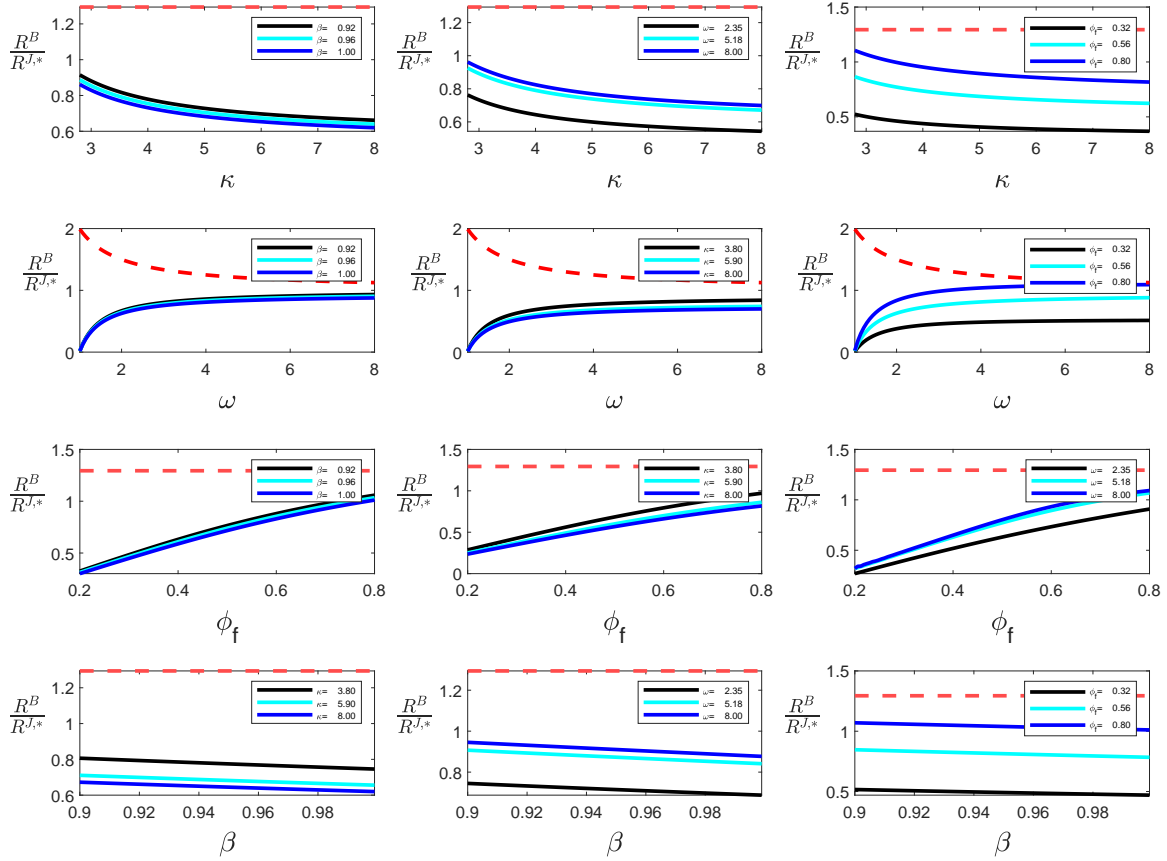


Figure D.7: Comparative Statics, Policy Room.

*Notes:* This figure display how  $\kappa$ ,  $\omega$ , and  $\phi_f$  affect the relationship between the policy room and the parameters.



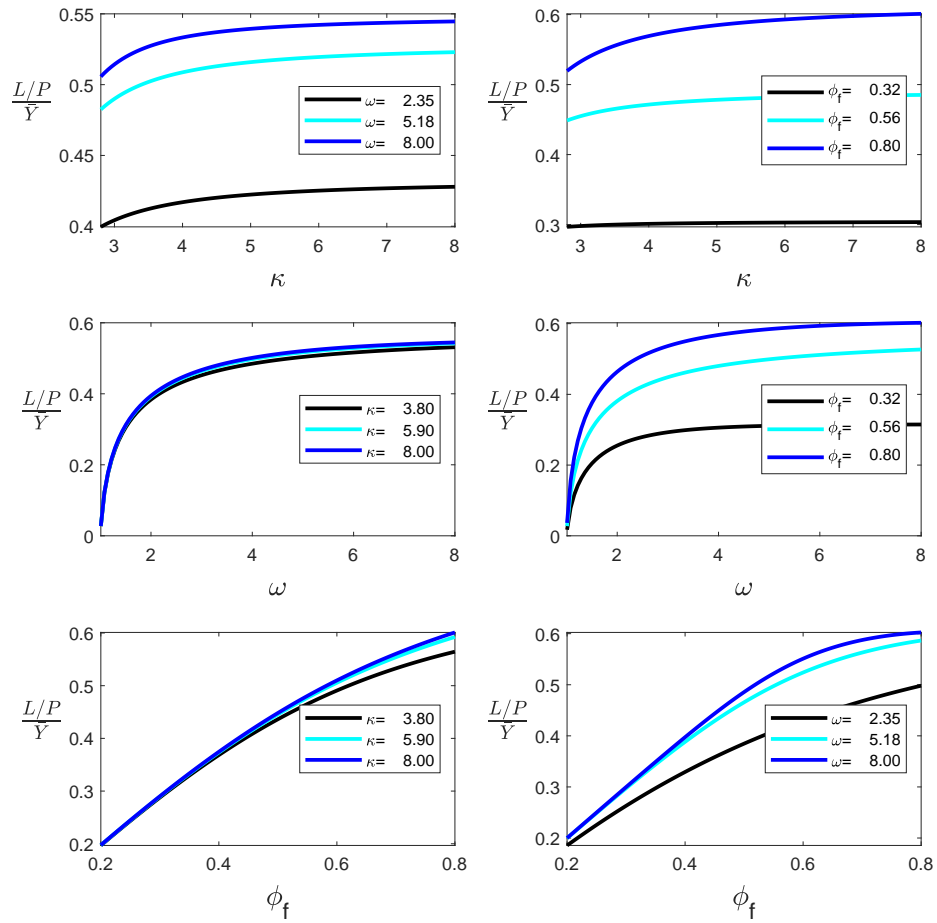


Figure D.8: Comparative Statics, Loan-to-output ratio.

Notes: This figure display how  $\kappa$ ,  $\omega$ , and  $\phi_f$  affect the relationship between  $\frac{L/P}{Y}$  and the parameters.

D.2 Section 4.1

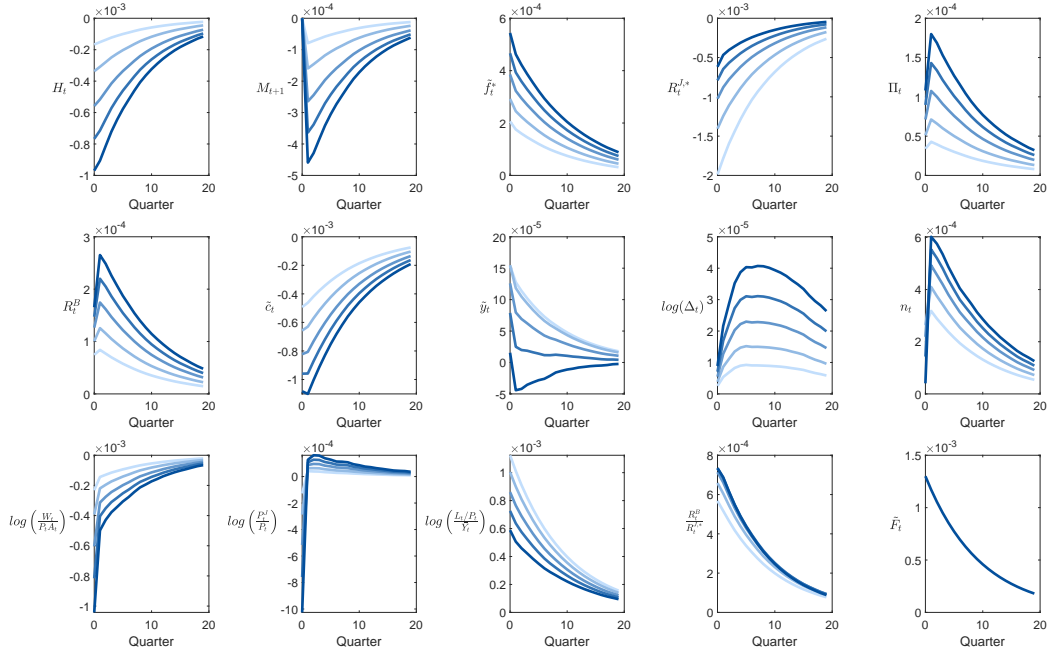


Figure D.9: Impulse response functions to fixed cost shock.

*Notes:* The figures display the impulse response functions to a one standard deviation shock (0.0013) in  $u_{f,t}$ , the fixed cost shock. The gradient blue lines denote the responses under calibrations with varying  $\phi_f$ . From light blue to dark blue,  $\phi_f$  values are 0.35, 0.45, 0.5547 (benchmark), 0.65, and 0.75. The following variables are plotted in deviations from their steady states:  $H$ ,  $M$ ,  $R^B$ ,  $\Pi$ , and  $R^{J,*}$ . The remaining variables are plotted in log deviations from their steady states (in lower case letters or with a log).  $\Delta$  represents the price dispersion for the downstream products.  $W_t/(P_t A_t)$  is the real wage.  $P_t^J/P_t$  measures the aggregate price for the upstream products or the input price for the downstream firms.

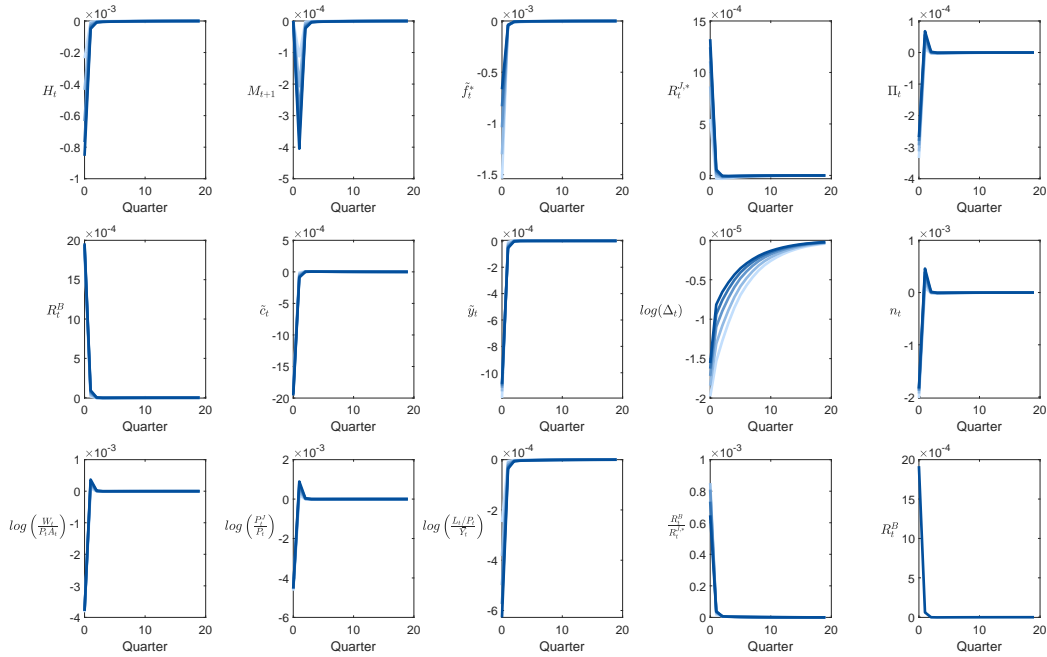


Figure D.10: Impulse response functions to monetary policy shock.

*Notes:* The figures display the impulse response functions to a one standard deviation shock (0.0025) in  $\epsilon_{r,t}$ , the monetary policy shock. The gradient blue lines denote the responses under calibrations with varying  $\phi_f$ . From light blue to dark blue,  $\phi_f$  values are 0.35, 0.45, 0.5547 (benchmark), 0.65, and 0.75. The following variables are plotted in deviations from their steady states:  $H$ ,  $M$ ,  $R^B$ ,  $\Pi$ , and  $R^{J,*}$ . The remaining variables are plotted in log deviations from their steady states (in lower case letters or with a log).  $\Delta$  represents the price dispersion for the downstream products.  $W_t/(P_t A_t)$  is the real wage.  $P_t^J/P_t$  measures the aggregate price for the upstream products or the input price for the downstream firms.

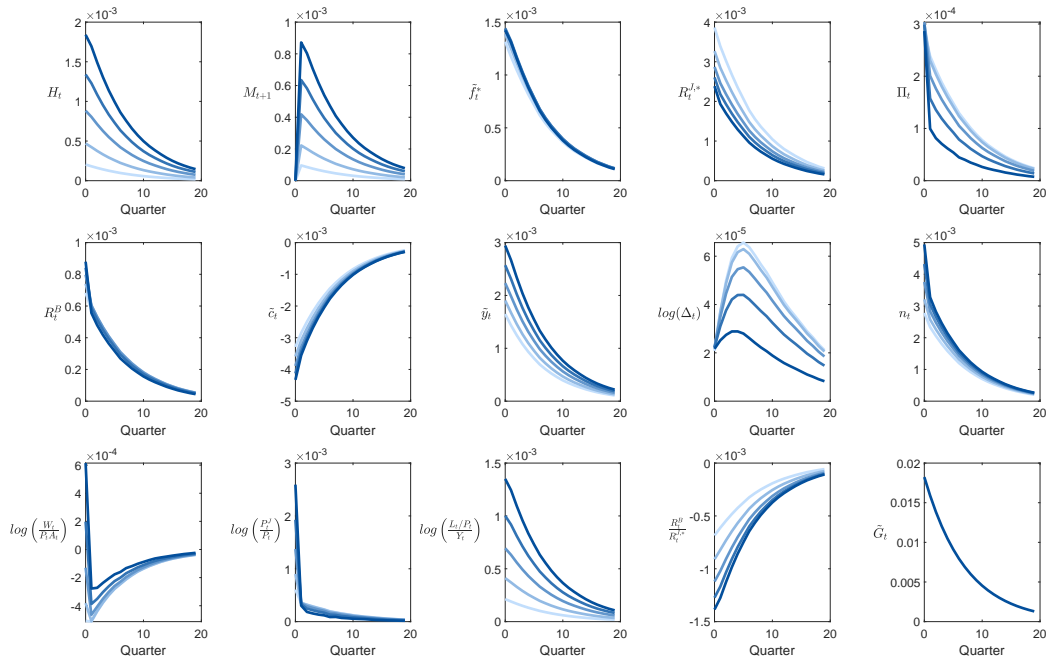


Figure D.11: Impulse response functions to government spending shock.

*Notes:* The figures display the impulse response functions to a one standard deviation shock (0.016) in  $u_{g,t}$  which denotes the government spending shock. The gradient blue lines denote the responses under calibrations with varying  $\phi_f$ . From light blue to dark blue,  $\phi_f$  values are 0.35, 0.45, 0.5547 (benchmark), 0.65, and 0.75. The following variables are plotted in deviations from their steady states:  $H$ ,  $M$ ,  $R^B$ ,  $\Pi$ , and  $R^{J,*}$ . The remaining variables are plotted in log deviations from their steady states (in lower case letters or with a log).  $\Delta$  represents the price dispersion for the downstream products.  $W_t/(P_t A_t)$  is the real wage.  $P_t^J/P_t$  measures the aggregate price for the upstream products or the input price for the downstream firms.

## D.3 Section 4.3

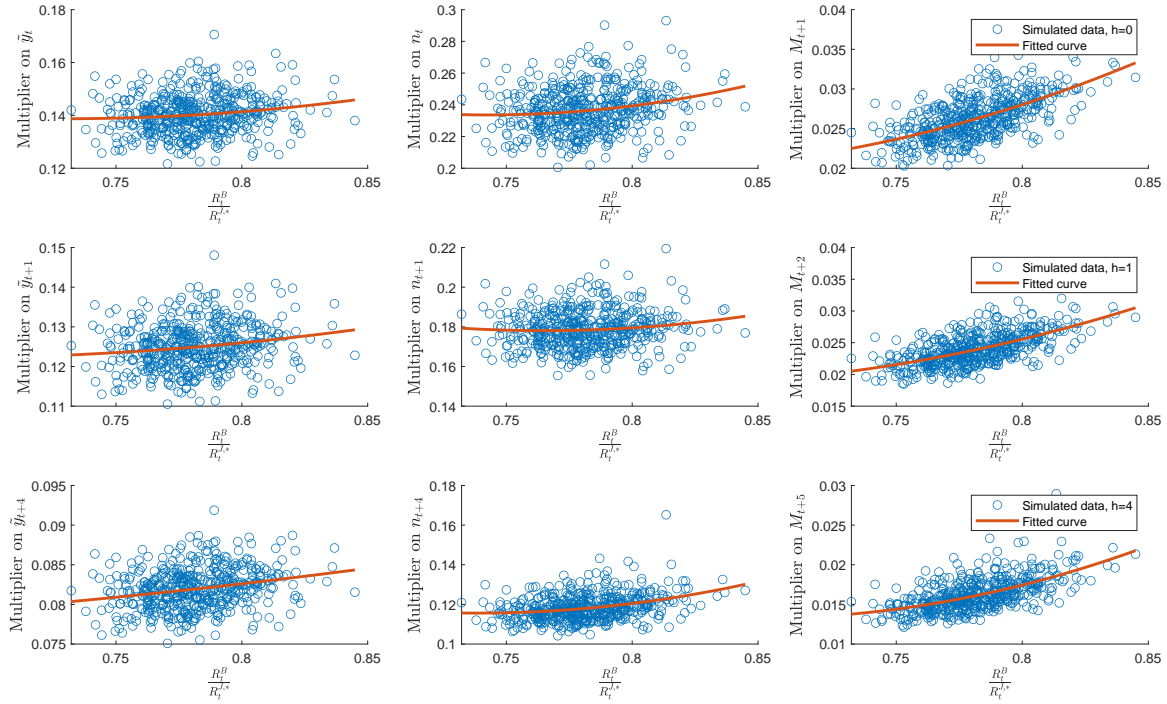


Figure D.12: Scatter plot between policy room and government spending multipliers.

*Notes:* Figures plot the relationship between policy room and government spending multipliers on output (in logs), labor (in logs), and next period mass of operating firms (in levels). We consider the next period's mass of operating firms since the firms paying the fixed cost at  $t$  will operate on the market at  $t + 1$ . Figures in the first to third rows display the contemporaneous multipliers ( $h = 0$ ), multipliers after 1 quarter ( $h = 1$ ), and multipliers after 4 quarters ( $h = 4$ ) correspondingly. The blue circles represent the result from each simulation based on solutions from the third-order perturbation method. The red solid lines are fitted second-order polynomials.

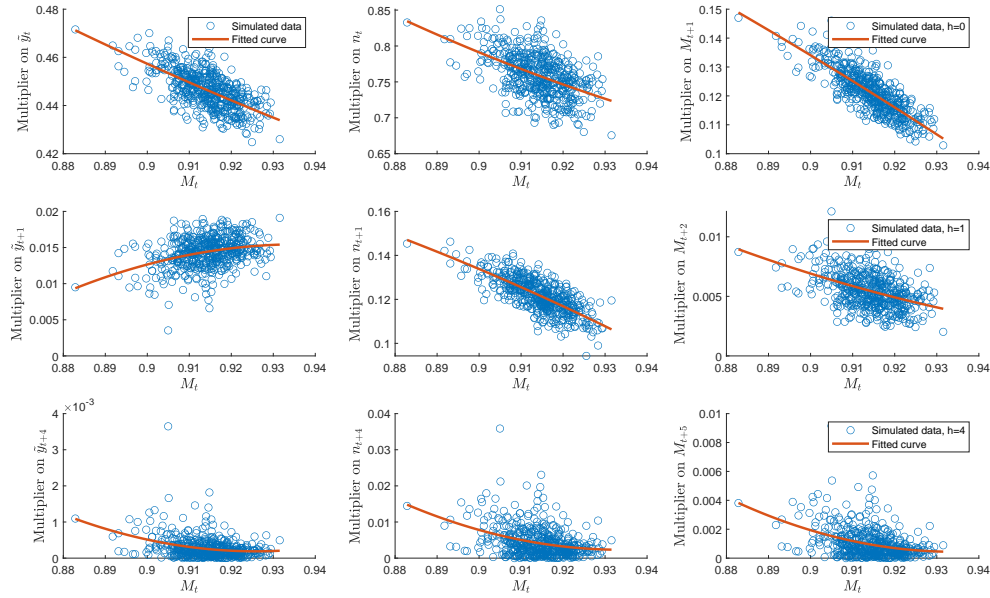


Figure D.13: Scatter plot between the mass of firms and monetary policy multipliers.

*Notes:* Figures plot the relationship between the current mass of operating firms and monetary policy multipliers on output (in logs), labor (in logs), and next period mass of operating firms (in levels). We consider the next period's mass of operating firms since the firms paying the fixed cost at  $t$  will operate on the market at  $t + 1$ . Figures in the first to third rows display the contemporaneous multipliers ( $h = 0$ ), multipliers after 1 quarter ( $h = 1$ ), and multipliers after 4 quarters ( $h = 4$ ) correspondingly. The blue circles represent the result from each simulation based on solutions from the third-order perturbation method. The red solid lines are fitted second-order polynomials.

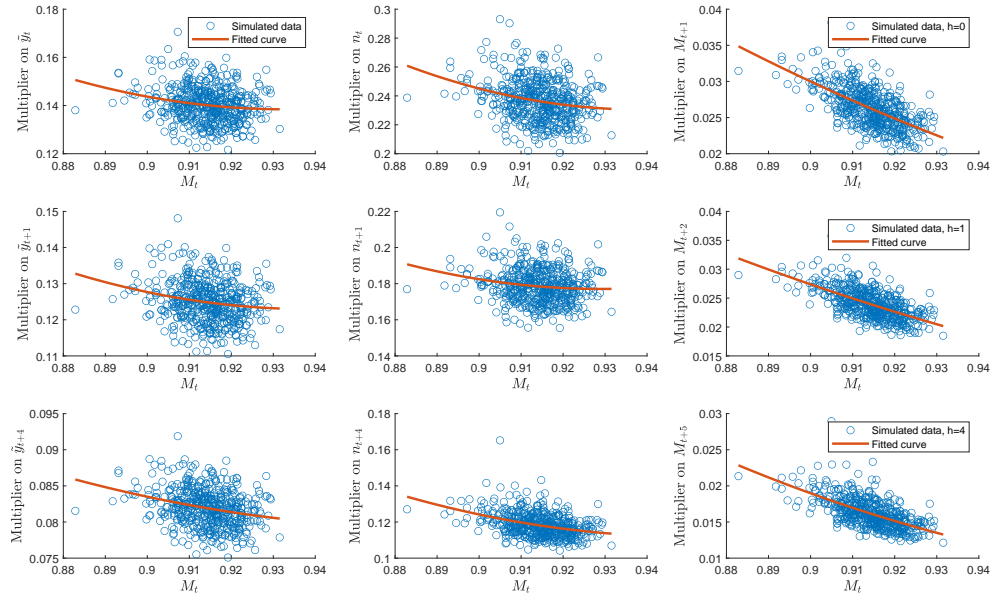


Figure D.14: Scatter plot between the mass of firms and government spending multipliers.

*Notes:* Figures plot the relationship between the current mass of operating firms and government spending multipliers on output (in logs), labor (in logs), and next period mass of operating firms (in levels). We consider the next period's mass of operating firms since the firms paying the fixed cost at  $t$  will operate on the market at  $t + 1$ . Figures in the first to third rows display the contemporaneous multipliers ( $h = 0$ ), multipliers after 1 quarter ( $h = 1$ ), and multipliers after 4 quarters ( $h = 4$ ) correspondingly. The blue circles represent the result from each simulation based on solutions from the third-order perturbation method. The red solid lines are fitted second-order polynomials.

### E Robustness in Section 5

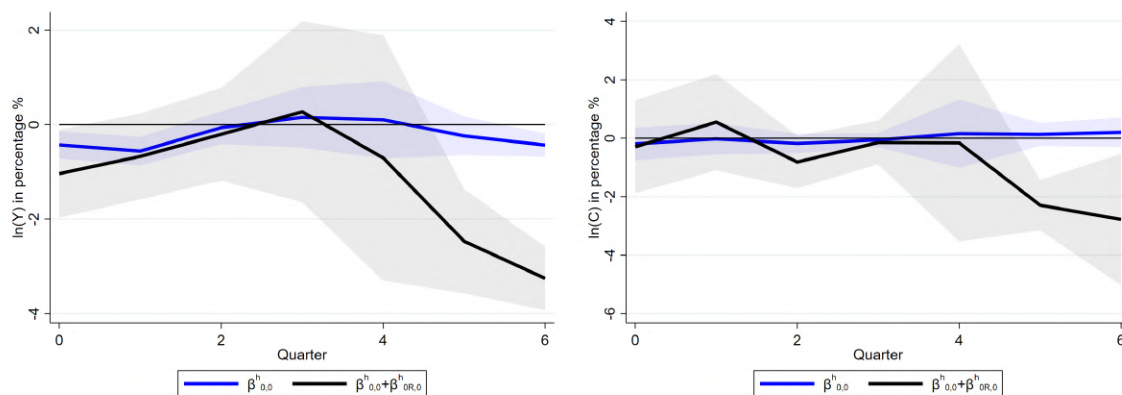
#### E.1 Robustness: the Policy Room Recovered by Version 1

Now, we run our benchmark regression based on the policy room measure recovered by Version 1 in Appendix C.1 and Appendix C.4, based on the total number of employees from CES National Databases in the Bureau of Labor Statistics (BLS). In this case, we use monetary shock series from either [Wieland and Yang \(2020\)](#) or [Acosta \(2023\)](#), who both extended the shock series of [Romer and Romer \(2004\)](#).

Figures E.15 (with [Wieland and Yang \(2020\)](#) monetary policy shock series) and E.16 (with [Acosta \(2023\)](#) shock series) display the impulse response functions of output, consumption, and unemployment to monetary policy shocks and the interaction of monetary policy shocks with policy room deviation constructed from Version 1 (with the employment measured by the number of employees from BLS). Overall results are similar, even if they become less significant with [Acosta \(2023\)](#) and the policy room constructed with Version 1. As our model lacks physical capital, using the formula for labor demand (i.e., equation (25)) to recover the satiation measure  $H_t$  and the policy room  $\frac{R_t^B}{R_t^{J,*}}$  might overemphasize the role of the policy room in driving labor demand fluctuations, lowering the significance of the results.

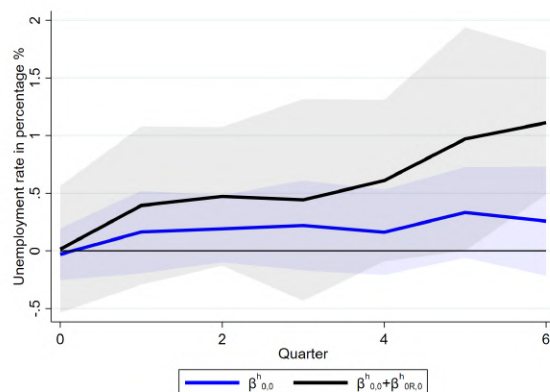
**With Additional Controls** We add more controls to our benchmark regression with the policy room measure recovered from Version 1 and test the robustness of our results. The controls are current and four lags of federal funds rates, four lags of oil price growth rate, four lags of long-term interest rate, four lags of consumption growth rate, four lags of GDP deflator, four lags of shadow federal funds rate from [Wu and Xia \(2016\)](#). Figure E.17 shows that the additional controls produce little to no difference in the impulse responses of the selected variables compared to the benchmark specification displayed in Figure E.16.





(a)  $\log(Y)$  with **Wieland and Yang (2020)**

(b)  $\log(C)$  with **Wieland and Yang (2020)**



(c) Unemployment rate with **Wieland and Yang (2020)**

Figure E.15: Local projection with policy room from Version 1.

*Notes:* The impulse response functions are based on the benchmark regression with monetary policy shocks from **Wieland and Yang (2020)**, which controls for current and four lags of federal funds rate. The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

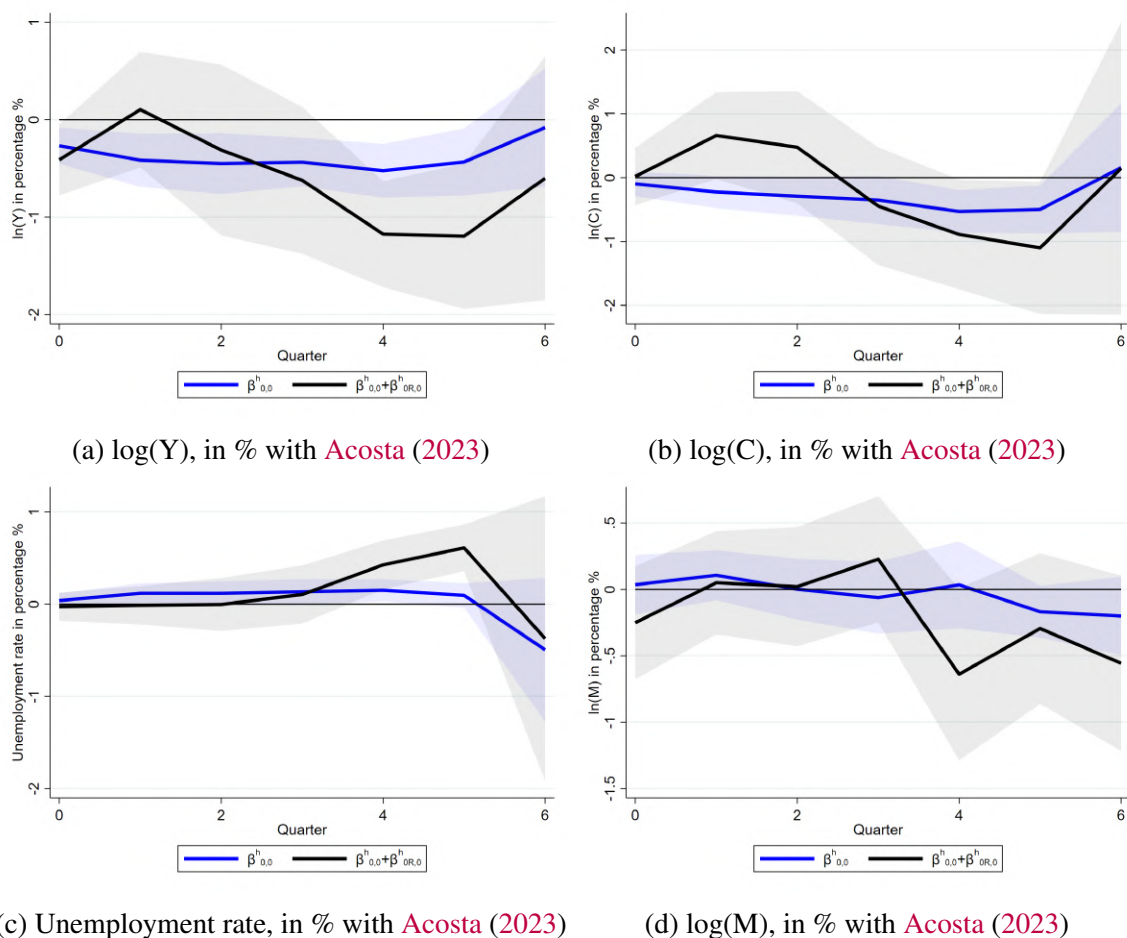


Figure E.16: Local projection with policy room from Version 1.

*Notes:* The impulse response functions are based on the benchmark regression with monetary policy shocks from Acosta (2023), which controls for current and four lags of federal funds rate. The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

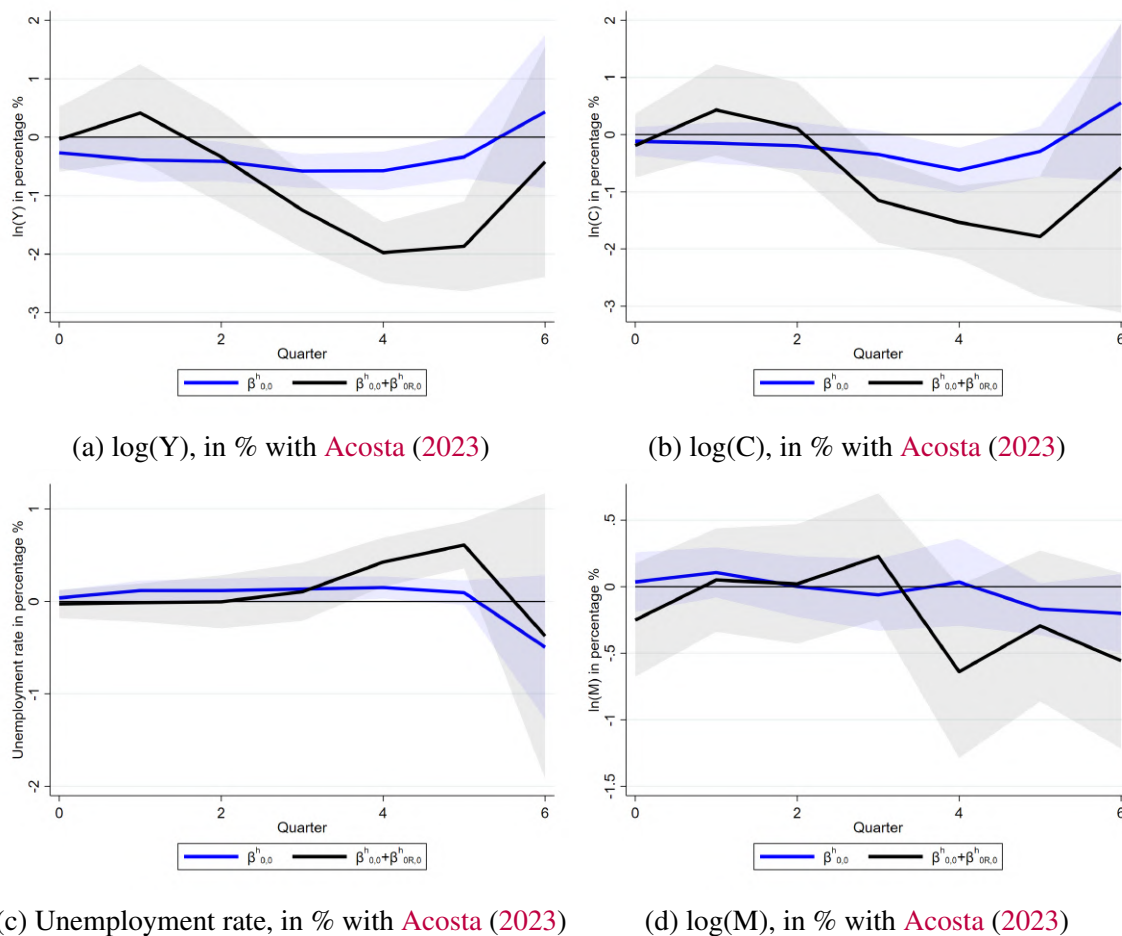


Figure E.17: Local projection with policy room from Version 1 and additional controls.

*Notes:* The impulse responses functions are for the local projection with the following additional controls: four lags of the oil price growth rate, four lags of the long-term interest rate, four lags of the consumption growth rate, four lags of the GDP deflator, and four lags of the shadow federal funds rate from Wu and Xia (2016). The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

## Online Appendix: For Online Publication Only

**Without Interaction** We test the effectiveness of monetary shocks without introducing the interaction term with the policy room, i.e.,  $\beta_{0R,p}^{(h)} = 0$ . Figures E.19 (with [Wieland and Yang \(2020\)](#) shocks) and E.18 (with [Acosta \(2023\)](#) shocks) illustrate the impulse response functions of log output, log private consumption and the unemployment rate to a unit of contractionary monetary policy shocks following the method proposed by [Romer and Romer \(2004\)](#). We observe that monetary policy has mostly significant effects on output, consumption, unemployment rate, and firm entry.

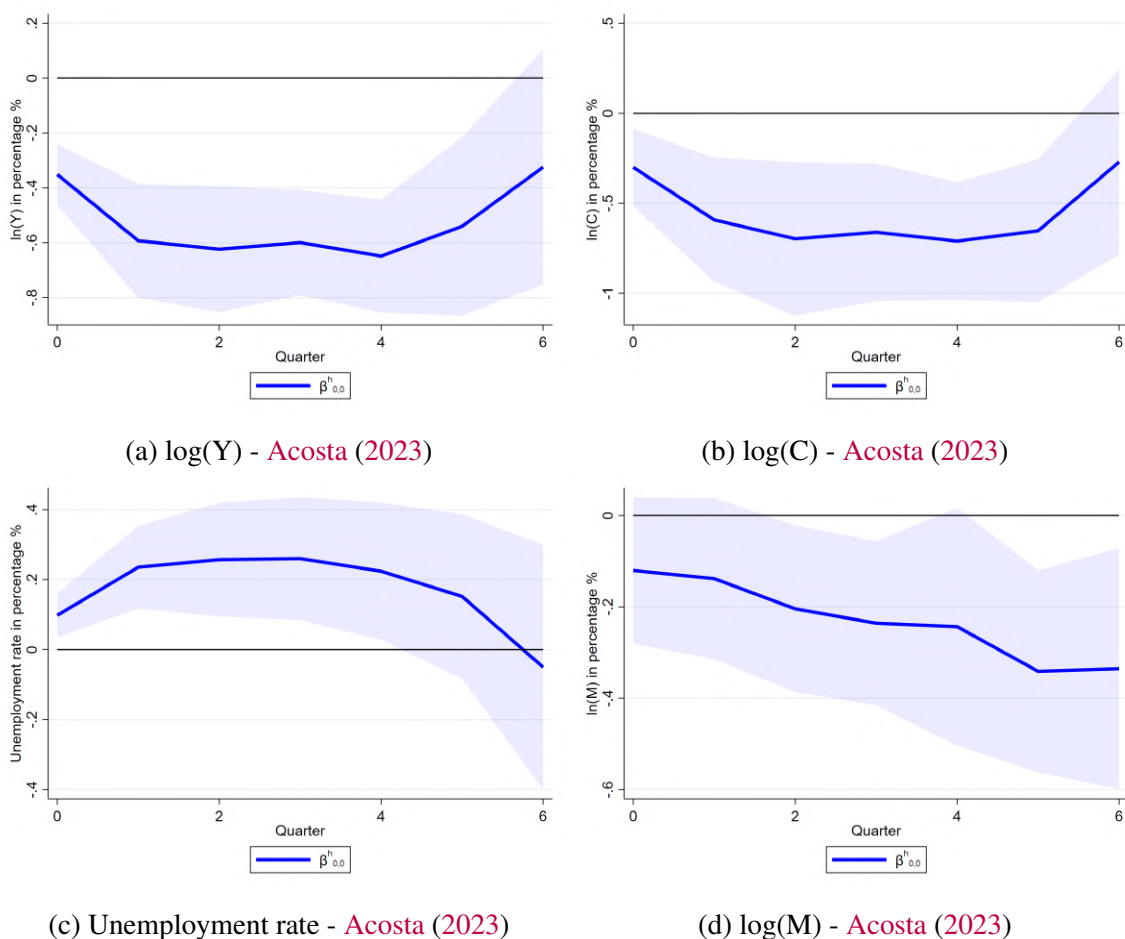


Figure E.18: Local projection without interactions.

*Notes:* The impulse response functions are based on the benchmark regression without the interaction term, with monetary policy shocks from [Acosta \(2023\)](#), and controls for current and four lags of federal funds rate. The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

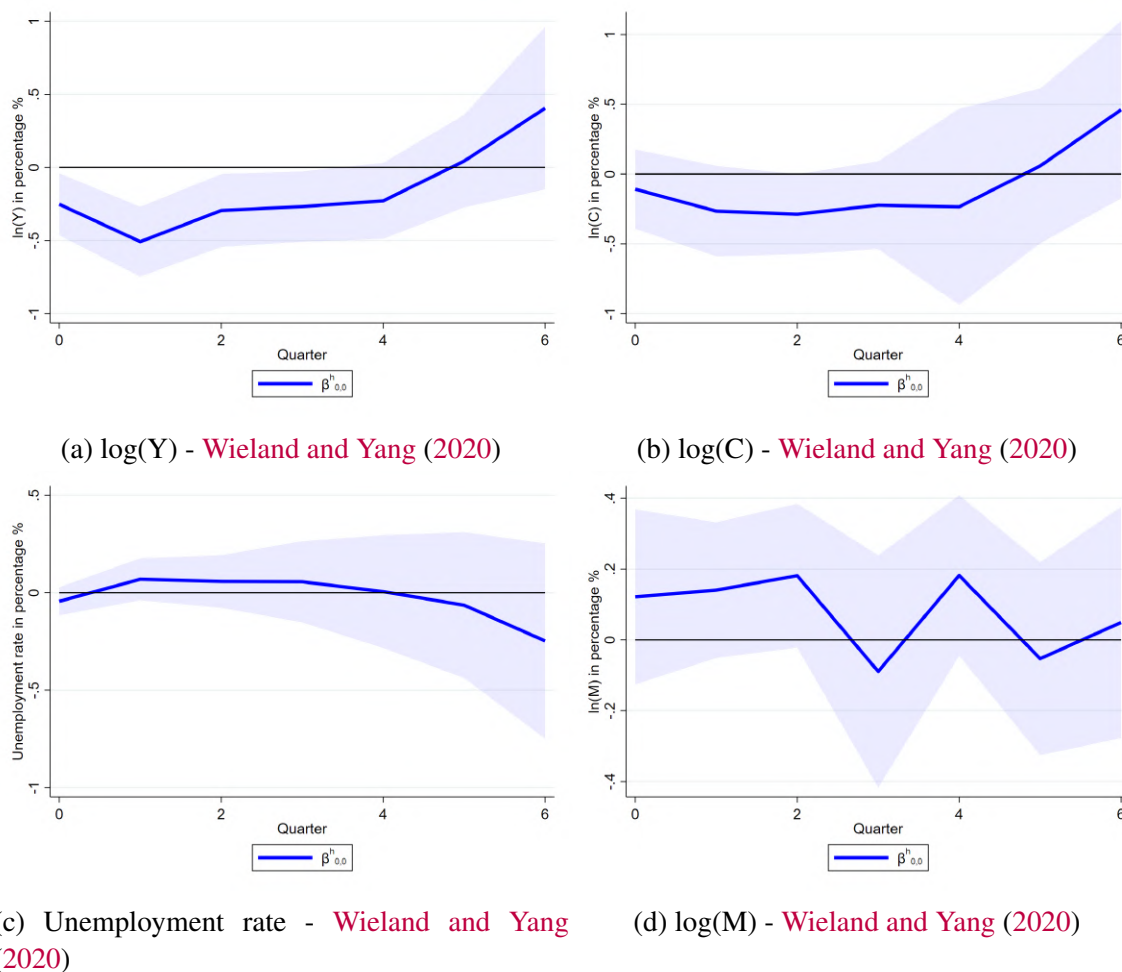


Figure E.19: Local projection without interactions.

*Notes:* The impulse response functions are based on the benchmark regression without the interaction term, with monetary policy shocks from [Wieland and Yang \(2020\)](#), and controls for current and four lags of federal funds rate. The figure reports the 95% confidence band, constructed using Newey-West standard errors under the assumption of serial correlation of the same lag length as the regression horizon,  $h$ .

## E.2 Robustness: lag length

We summarize the results with the number of lags different from four, our benchmark number used in Section 5 and Appendix E.1, as follows:

### Change 1 Number of lags being 2 instead of 4

- (a) Impulse response functions with shocks of [Wieland and Yang \(2020\)](#) become smoother, with less spiky (also wider and insignificant) confidence bands.
- (b) Impulse response functions with shocks of [Acosta \(2023\)](#) are robust when the number of lags in controls changes from 4 to 2, making the results look slightly more significant (the initial positive responses of  $\beta_{OR}$  become smaller and insignificant for output and consumption, thus the later negative responses stand out more significant for output and consumption. Also, the confidence bands for unemployment become narrower for Version-1-based policy room.
- (c) Impulse response functions with shocks of [Acosta \(2023\)](#) with Version-2-based policy room (our benchmark result in Section 5) do not change much.

### Change 2 Number of lags being 6 instead of 4

- (a) Controlling more lags makes the confidence bands of the results with shocks of [Wieland and Yang \(2020\)](#) narrower.
- (b) With the number of lags being 6 and the policy room recovered by Version 1, the results become worse with shocks of [Acosta \(2023\)](#): initial positive responses in  $\beta_{OR}$  become more significant and later negative responses are less significant for output and consumption, with larger confidence bands for responses in unemployment.
- (c) Impulse response functions with shocks of [Acosta \(2023\)](#) with Version-2-based policy room (our benchmark result in Section 5) do not change much.<sup>5</sup>

## F Limiting Case with $\omega \rightarrow \infty$

When  $\omega \rightarrow +\infty$ , the Pareto distribution  $H(F_{m,t})$  of the fixed costs collapse to its mean,  $F_t$ . In this scenario, it is trivial to see that  $P_{m,t}^J = P_t^J$ . For  $P_t^J$ , we plug equation (A.5) into

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<sup>5</sup>The results with too many controls display more spikiness with not-well-behaved confidence intervals though.

## Online Appendix: For Online Publication Only

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equation (A.3), and obtain

$$\frac{P_t^J}{P_t} = \begin{cases} \Theta_1^{-\frac{\alpha+\sigma(1-\alpha)}{(\sigma-1)\alpha}} \left( \frac{W_t}{P_t A_t} \right) \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1-\alpha}{\alpha}} \\ \cdot \left( \frac{R_{t-1}^J F_{t-1}}{\Theta_2 E_{t-1} \left[ \xi_t \left( \frac{P_t^J}{P_t} \right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left( \frac{W_t}{P_t A_t} \right)^{-\frac{(\sigma-1)\alpha}{\alpha+\sigma(1-\alpha)}} \left( \frac{\kappa-1}{\kappa} A_t \right) \Pi_t \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \right]} \right)^{\frac{[\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)](\alpha+\sigma(1-\alpha))}{(\sigma-1)^2 \alpha}} \\ \text{if } R_t^J > R_t^{J,*}, \\ \Theta_1^{-\frac{(\alpha+\sigma(1-\alpha))}{(\sigma-1)\alpha}} \left( \frac{W_t}{P_t A_t} \right) \cdot \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1-\alpha}{\alpha}} \text{ if } R_t^J \leq R_t^{J,*}. \end{cases} \quad (\text{F.1})$$

Plugging (F.1) into (A.5), we can obtain

$$\Xi_t = \begin{cases} \Theta_5 \cdot \left( \frac{W_t}{P_t A_t} \right) \left[ \left( \frac{\kappa-1}{\kappa} A_t \right)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \cdot P_t \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \right. \\ \cdot \left( \frac{R_{t-1}^J F_{t-1}}{\Theta_2 E_{t-1} \left[ \xi_t \left( \frac{P_t^J}{P_t} \right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left( \frac{W_t}{P_t A_t} \right)^{-\frac{(\sigma-1)\alpha}{\alpha+\sigma(1-\alpha)}} \left( \frac{\kappa-1}{\kappa} A_t \right)^{\frac{(\sigma-1)(1-\alpha)}{\alpha+\sigma(1-\alpha)}} \Pi_t(Y_t \Delta_t)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \right]} \right)^{\frac{\sigma}{\sigma-1} \left( \frac{\kappa[\alpha+\sigma(1-\alpha)]-(\sigma-1)}{(\sigma-1)\alpha} \right)} \\ \text{if } R_t^J > R_t^{J,*}, \\ \Theta_5 \cdot \left( \frac{W_t}{P_t A_t} \right) \left[ \left( \frac{\kappa-1}{\kappa} A_t \right)^{\frac{1}{\alpha+\sigma(1-\alpha)}} \cdot P_t \left( \frac{Y_t \Delta_t}{A_t} \right)^{\frac{1}{\alpha}} \right] \text{ if } R_t^J \leq R_t^{J,*}, \end{cases} \quad (\text{F.2})$$

where we define

$$\Theta_5 = \Theta_1^{-\frac{\sigma}{(\sigma-1)\alpha}} \Theta_2 \left( \frac{\kappa-1}{\kappa} \right)^{\frac{\alpha(1-\sigma)-1}{\alpha+\sigma(1-\alpha)}}.$$

Now that  $M_t = M_{m,t}$ ,  $L_t = L_{m,t}$ ,  $R_t^{J,*} = R_{m,t}^{J,*}$  and  $\varphi_t^* = \varphi_{m,t}^*$ , we can substitute (F.2) into (14), (15), (16), and (17) to obtain following analytical expressions:

$$R_t^{J,*} = \Theta_5 \cdot E_t \left[ \xi_{t+1} \left( \frac{\kappa-1}{\kappa} A_{t+1} \right)^{\frac{\sigma}{\alpha+\sigma(1-\alpha)}} \left( \frac{w_{t+1}}{P_{t+1} A_{t+1}} \right) \frac{\Pi_{t+1}}{F_t} \left( \frac{Y_{t+1} \Delta_{t+1}}{A_{t+1}} \right)^{\frac{1}{\alpha}} \right],$$

and

$$\varphi_t^* = \left( \frac{R_t^J}{R_t^{J,*}} \right)^{\left( \frac{\alpha + \sigma(1-\alpha)}{\sigma-1} \right)} \left[ \left( \frac{\kappa-1}{\kappa} \right) A_{t+1} \right], \quad (\text{F.3})$$

$$M_{t+1} = \begin{cases} \left( \frac{R_t^J}{R_t^{J,*}} \right)^{-\left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\sigma-1} \right)} & \text{if } R_t^J > R_t^{J,*}, \\ 1 & \text{if } R_t^J \leq R_t^{J,*}, \end{cases} \quad (\text{F.4})$$

$$L_t = \begin{cases} \left( \frac{R_t^J}{R_t^{J,*}} \right)^{-\left( \frac{\kappa[\alpha + \sigma(1-\alpha)]}{\sigma-1} \right)} \cdot F_t & \text{if } R_t^J > R_t^{J,*}, \\ F_t & \text{if } R_t^J \leq R_t^{J,*}. \end{cases} \quad (\text{F.5})$$

We observe: if  $R_t^J \leq R_t^{J,*}$ , where  $R_t^{J,*}$  is defined in (22), all firms are satiated and the loan amount made to firms is equal to  $F_t$ , the fixed cost that operating firms need to pay one period in advance.

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