

Competition, Financial Constraints and Misallocation: Plant-Level Evidence from Indian Manufacturing

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Abstract

This paper combines a novel general equilibrium model with evidence from Indian plant-level data to investigate the relationship between competition, financial constraints and misallocation. In the theoretical model, steady-state misallocation arises both from variation in markups, and from the interaction of firm-level productivity volatility with financial constraints. Firms experience random, positive shocks to their productivity, in response to which they optimally grow their capital stock, subject to financial constraints. Competition plays a dual role in affecting misallocation. On the one hand, both markup levels and markup dispersion tend to fall with competition, which unambiguously improves allocative efficiency in a setting without financial constraints. On the other hand, in a setting with financial constraints, a reduction in markups slows down capital accumulation, as the rate of self-financed investment shrinks. Thus, the positive impact of competition on steady-state misallocation is reduced by the presence of financial constraints. Empirically, I test and confirm the qualitative predictions of the model with data on Indian manufacturing. The prediction that the firm-level speed of capital convergence falls with competition is confirmed for the full panel of manufacturing plants in India's Annual Survey of Industries. This effect is particularly pronounced in sectors with higher levels of financial dependence. I also exploit natural variation in the level of competition, arising from the pro-competitive impact of India's 1997 dereservation reform on incumbent plants, and again confirm the qualitative predictions of the model.

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1 Introduction

Misallocation of resources has recently become a prominent explanation for cross-country differences in economic development. For instance, [Hsieh and Klenow \(2009\)](#) argue that misallocation, arising from the misalignment of marginal products across plants, could account for 40 to 60% of the difference in aggregate output per capita between the United States and India. This finding has sparked a debate on the main driving forces of the pattern in measured misallocation across countries. For instance, dispersion in the marginal revenue products of capital (MRPK), central to this paper's analysis, can be explained by either technological constraints, market imperfections or policy distortions.¹ Knowledge on the relative importance of these different underlying mechanisms matters to understand the potential level of macroeconomic efficiency gains from specific policy interventions.

This paper contributes to the above debate by investigating the relationship between competition, financial constraints and misallocation. Theoretically, existing work ([Epifani and Gancia, 2011](#); [Peters, 2013](#)) explains how in a setting with variable markups, competition reduces misallocation by decreasing dispersion in markups. While this channel is still present in my analysis, I demonstrate that financial constraints reduce the positive impact of competition on misallocation. Specifically, I show that competition slows down the capital growth rate of financially constrained firms and thereby capital wedges, resulting from the difference between first-best and actual capital levels, are amplified by competition. Intuitively, firm-level markups fall with the degree of competition, which lowers the scope for internally financed capital accumulation. I then empirically test and confirm the qualitative predictions of the model with data on the Indian manufacturing sector.

In the model, capital misallocation arises due to the interaction of productivity volatility and financial constraints. Productivity volatility implies that firms experience random shocks to their idiosyncratic levels of productivity. After a positive productivity shock, a firm will optimally choose to grow its capital stock, but the financial constraint will limit its ability to do so. Therefore, the scope for internal financing, governed by the level of markups in the industry, codetermines the speed of convergence to the firm's optimal capital level. Since competition reduces the level of markups, it will negatively affect a firm's speed of capital convergence in response to a positive productivity shock. This way, capital wedges are amplified by competition.

A related channel through which competition can negatively affect capital misallocation applies to young plants in particular. In an extension of the model, newborn firms are assumed

¹Roughly speaking, capital misallocation is a function of the dispersion in marginal revenue products of capital (MPRK). As such it is a salient component of aggregate misallocation. [Asker et al. \(2014\)](#) propose a model where such dispersion in MRPK is explained by adjustment costs in capital, which is a form of technological constraints. In this case, the dispersion in MRPK is the consequence of first-best optimization, and does not constitute a *misallocation* of capital. In other settings measured dispersion in MRPK arises from market imperfections or policy distortions. In [Midrigan and Xu \(2014\)](#) and [Moll \(2014\)](#) the explanation for capital misallocation relies on market imperfections as firms' collateral constraints arise from imperfect financial markets. [Restuccia and Rogerson \(2008\)](#), in their seminal contribution to the misallocation literature, model misallocation as the result of firm-level variation in taxes or subsidies, with a non-competitive banking sector varying its interest rates for noneconomic reasons as a leading example. [Restuccia and Rogerson \(2013\)](#) provide a broader survey of the misallocation literature.

to be undercapitalized and therefore financially constrained. As such, these firms will also rely on internal financing while converging to their optimal level of capital. This implies that competition again reduces the speed of capital convergence by reducing the scope for internal finance, thereby amplifying capital wedges.²

I then test the predictions of the model in the context of the Indian manufacturing sector. I first test the main mechanism of the model, namely that firm-level speed of capital convergence decreases with competition. This prediction can be tested at two levels: for firms in general and for young plants in particular. For firms in general, I test whether, after a firm deviates from its optimal marginal revenue product of capital (MRPK), it converges back faster to its optimal MRPK in a setting with less competition. Then, based on the model's prediction for undercapitalized young plants, I check if the capital growth rate of young plants is faster in settings where competition is less intense. These two empirical tests are complementary. The first test is closely linked to the structure of the model as it focuses directly on plant-level MRPK, where, inspired by (Asker et al., 2014), plant-level deviations in MRPK serve as a proxy of the plant-level capital wedges. The second test, which focuses on young plants, has the advantage that capital-growth is a reduced-form object in the data, and therefore relies on fewer assumptions for its measurement. The fact that both tests empirically validate the model predictions, therefore provides robust support for the model.

A second set of tests leverages heterogeneity in firms' financial dependence, where capital convergence of firms in sectors with higher financial dependence exhibits a stronger sensitivity to the degree of competition. To test this prediction, I augment the baseline tests with an interaction term of the competition measure with Rajan and Zingales (1998) measures of sector-level financial dependence. The data again support the predictions, both for the test on MRPK convergence, and for the test on capital growth for young firms.

These two sets of predictions rely on a measure for competition that is arguably exogenous from the firm's point of view, namely the median markup measured at the state-sector level. The advantage of this approach is that I can test the theory on a large subset of the Indian manufacturing sector, while a potential limitation is that the underlying structural drivers of the variation in state-sector levels of competition remain unexamined. To address this concern, I also exploit natural variation in the degree of competition arising from India's 1997 dereservation reform, and now test whether convergence of MRPK is slower after dereservation, and whether young plants grow capital more slowly after dereservation.³ The data again confirm the two predictions of the model.

The theory builds on Midrigan and Xu (2014), who examine comparative statics for steady-state capital misallocation in a setting of imperfect competition. Since they employ simulation-

²As a preliminary empirical check, I provide evidence that the two fundamental sources underlying capital misallocation in the model - productivity volatility and the rate of arrival of newborn firms - are empirically salient in the Indian manufacturing sector.

³The dereservation reform gradually removed previously existing investment ceilings on a set of "reserved" products (García-Santana and Pijoan-Mas, 2014; Martin et al., 2014; Tewari and Wilde, 2014). Hence, the direct effect of dereservation is to allow incumbent firms to increase their capital stock. However, the reform also leads to intensified competition, e.g. through larger firms starting to produce the previously reserved products, and this competitive channel empirically dominates in my analysis of capital convergence.

based methods, the current paper theoretically contributes to the literature by providing an analytical solution for capital misallocation as a function of competition. The main focus of [Midrigan and Xu \(2014\)](#) is in quantifying the relative importance of barriers to entry versus collateral constraints for incumbent firms in shaping misallocation. This paper's focus on the comparative statics for competition is therefore complementary to their analysis.

[Moll \(2014\)](#) and [Itskhoki and Moll \(2015\)](#) also analyze capital misallocation analytically. However, they do so in a setting of perfect competition, whereas I study the impact of varying levels of imperfect competition. This focus on the impact of competition on misallocation entails this paper shares the orientation on policy with [Itskhoki and Moll \(2015\)](#), who study the impact of taxation policy on capital misallocation.⁴ However, they focus on the role for policy along the transition path from an undercapitalized economy to the steady-state, whereas I analyze steady-state misallocation.

By examining the potential downsides of intensified competition, this paper complements papers that emphasize the beneficial impacts of competition on misallocation. For instance, [Peters \(2013\)](#) argues that increased competition diminishes misallocation, as it reduces the dispersion in the distribution of markups. A second, well-established, beneficial impact of competition consists in reallocating labor from low productivity to high productivity firms. Here, [Melitz \(2003\)](#) studies the role of trade liberalization in improving the allocative efficiency of labor, and [Akcigit et al. \(2014\)](#) analyze constraints to such reallocation through competition in a Schumpeterian growth model with firm-level limits to delegation.

The analysis by [Akcigit et al. \(2014\)](#) is motivated by the stylized fact on firm-stagnation in India ([Hsieh and Klenow, 2014](#)). This slow growth of firms is part of the broader lack of reallocation and persistent level of misallocation in the Indian manufacturing sector, as analyzed by [Bollard et al. \(2013\)](#). This paper aims to contribute to our understanding of this high and persistent level of misallocation in the Indian manufacturing sector. As indicated above, the adverse effect of competition depends, amongst others, on the degree of productivity volatility and the entry-rate of newborn firms in a context of financial constraints. The stylized facts indicate that all these factors are substantially present in Indian manufacturing. First, for productivity volatility, [Asker et al. \(2014\)](#) demonstrate that there is a strong correlation between productivity volatility and their measure of capital misallocation in the case of India. Second, [Bollard et al. \(2013\)](#) document high entry-rates of new firms in Indian manufacturing. Third, [Banerjee and Duflo \(2014\)](#) estimate severe credit constraints for large Indian firms, which is consistent with the descriptive evidence on financial constraints from the World Bank Enterprise Surveys ([Kuntchev et al., 2014](#)). Together, these three stylized facts on productivity volatility, arrival rate of newborn firms, and financial constraints, indicate the relevance of this paper for understanding misallocation in Indian manufacturing.

⁴Generally in models with financial frictions, the first-best policy consists in removing such financial frictions. The focus on taxation policy in [Itskhoki and Moll \(2015\)](#) arises from a second-best perspective. The analysis of competition policy can also be understood from a second-best policy perspective.

2 Theory

2.1 Setup of the economy

Agents The economy has two sets of agents: workers and firm-owners. The measure L of workers supplies labor inelastically, and each worker is hired at a wage w_t , where t indicates the time period. A worker's consumption c_{it} is hand-to-mouth.

There is an exogenous, finite set M of firm-owners.⁵ Firm-owner i has the following intertemporal preferences at time t :

$$U_{it} = \sum_{s=t}^{\infty} \beta^{s-t} d_{is}$$

Where β is the discount factor and d_{it} is firm-owner consumption (d refers to dividend).⁶

Production of varieties Each firm produces a variety i with a Cobb-Douglas production function, using capital k_{it} and labor l_{it} as inputs:

$$y_{it} = a_{it} k_{it}^{\alpha} l_{it}^{1-\alpha} \quad (1)$$

Productivity a_{it} follows a stochastic process over the state-space $a_{it} \in \{a_L, a_H\}$, where $a_L < a_H$.⁷ Firm-level productivity volatility, arising from this stochastic path of a_{it} , will be central in the analysis of steady-state firm-dynamics in section 2.4. It is also crucial that capital is a dynamic input, subject to the equation of motion:

$$k_{it+1} = x_{it} + (1 - \delta)k_{it}$$

with investment x_{it} taking place, and being financed at the end of period t . The decision about labor l_{it+1} is also made in period t , i.e. at the same time the decision on k_{it+1} is made, but labor l_{it+1} is only paid at the end of period $t + 1$.⁸

Demand Investment x_{it} , workers' consumption c_{it} and firm-owner consumption d_{it} all consist of shares of the final good Q_t , which is composed of varieties q_{it} :

$$Q_t \equiv M^{1-\frac{1}{\eta}} \left[\sum_{i=1}^M q_{it}^{\eta} \right]^{\frac{1}{\eta}} \quad (2)$$

⁵The main comparative statics within the model will be on M , as modifying the degree of competition. Having M as exogenous simplifies the analytical solution of the model. In a simulation-based methodology, as employed by [Midrigan and Xu \(2014\)](#), one can endogenize the degree of competition.

⁶The simplifying assumption of linear firm-owner preferences will prove useful in the analytical derivation of a global solution for the firm-level path of capital.

⁷I follow [Midrigan and Xu \(2014\)](#) by assuming that in period t , the firm is informed about the distribution of a_{it+1} .

⁸The assumption of labor and capital being decided simultaneously, will simplify the optimization problem.

where $M^{1-\frac{1}{\eta}}$ eliminates taste-for-variety (Blanchard and Kiyotaki, 1987).⁹ ¹⁰ This expression for the composite good implies that firms face the following demand function q_{it} :

$$q_{it} = \left(\frac{p_{it}}{P_t} \right)^{-\frac{1}{1-\eta}} M^{-\frac{1}{\eta}} \left[\sum_{i=1}^M q_{it}^\eta \right]^{\frac{1}{\eta}} \quad (3)$$

where p_{it} is the price of variety i and P_t is the price of the final good:

$$P_t^{-\frac{\eta}{1-\eta}} \equiv \frac{1}{M} \sum_i p_{it}^{-\frac{\eta}{1-\eta}} \quad (4)$$

Financial constraint The above implies that firms face the following period-by-period budget constraint, where z_{it} is wealth at the end of period t : $z_{it} \equiv p_{it}y_{it} - w_t l_{it} + P_t(1 - \delta)k_{it}$.

$$P_t(k_{it+1} + d_{it}) \leq z_{it} \quad (5)$$

The financial constraint implies that consumption d_{it} cannot be negative:

$$d_{it} \geq 0 \quad (6)$$

2.2 Firm's problem

Market structure and firm problem I follow Atkeson and Burstein (2008) by assuming that each period, firms play a one-period game of quantity competition. Specifically, each firm i sets a quantity y_{it+1} for sale, conditional on the quantities chosen by the other firms in the economy. As discussed in the previous subsection, firms make decisions about l_{it+1}, k_{it+1} in period t , given the budget constraint $P_t(k_{it+1} + d_{it}) \leq z_{it}$ and knowing a_{it+1} . Therefore, any firm i 's optimal decisions are $k_{it+1}(a_{it+1}, z_{it}, \mathbf{y}_{-it+1})$, $l_{it+1}(a_{it+1}, z_{it}, \mathbf{y}_{-it+1})$, where (a_{it+1}, z_{it}) characterizes the state for firm i and \mathbf{y}_{-it+1} is the vector of decisions on y_{jt+1} for all $j \neq i$. Through the production function (1), the choice of k_{it+1}, l_{it+1} determines y_{it+1} and thereby $p_{it+1}(y_{it+1}, \mathbf{y}_{-it+1})$ as firms incorporate the demand function (3) into their optimization. As such, this setting entails the following intertemporal problem for the firm, where $\pi_{it}(k_{it}, l_{it}, \mathbf{y}_{-it}) \equiv p_{it}(y_{it}, \mathbf{y}_{-it})y_{it} - w_t l_{it}$:

⁹This expression for the final good is employed by Jaimovich (2007) in a setting with variable markups, and it allows to restrict attention to the competitive effects of varying M , and ignore the taste-for-variety effects. Bénassy (1996) generalizes this idea of de-linking consumption-side taste-for-variety and firm-level market power.

¹⁰There is one sector, and Q_t is the composite good of that sector. Note that it should be straightforward to extend this to a multi-sector case when preferences are Cobb-Douglas across sectors, as expenditure share are constant across sectors in that case.

$$\begin{aligned} \max_{d_{it}, k_{it+1}, l_{it+1}} \mathcal{L} = & \sum_{t=s}^{\infty} E_s [\beta^{t-s} d_{it}] + \\ & \sum_{t=s}^{\infty} E_s [\lambda_{it} (\pi_{it}(k_{it}, l_{it}, \mathbf{y}_{-it}) + P_t [(1 - \delta)k_{it} - k_{it+1} - d_{it}]) + \Phi_{it}(d_{it})] \end{aligned} \quad (7)$$

Since each firm's decision on y_{it+1} depends on $(a_{it+1}, z_{it}, \mathbf{y}_{-it+1})$, \mathbf{y}_{it+1} will be determined by $F(a(t+1), z(t))$, the joint distribution of a_{it+1} and z_{it} , and by the conditions in the labor and goods market implied by M, L .

$$\begin{aligned} k_{it+1} & (a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L) \\ l_{it+1} & (a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L) \end{aligned} \quad (8)$$

As explained, the optimal choices in (8) determine $p_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L)$, and given the firm's marginal cost thereby also determine the markup

$$\mu_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L) = \frac{\varepsilon_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L) - 1}{\varepsilon_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L)} \quad (9)$$

where the demand elasticity ε_{it} is:

$$\varepsilon_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)), M, L) = -\frac{1}{1-\eta} + \left(\frac{\eta}{1-\eta}\right) \frac{y_{it+1}^\eta}{\sum_i y_{it+1}^\eta} \quad (10)$$

Labor optimization The first-order condition for labor is standard:

$$E_s \left[\frac{\partial \pi_{it}(k_{it}, l_{it}, F(a(t+1), z(t)), M, L)}{\partial l_{it}} \right] = 0 \quad (11)$$

Intertemporal optimization Now I derive the first-order conditions for the dynamic part of the problem. Start with the first-order condition for d_{it} .

$$\frac{\partial \mathcal{L}}{\partial d_{it}} = \beta^{t-s} + E_s [-\lambda_{it} P_t + \Phi_{it}] = 0$$

Which implies the following condition:

$$\beta^{t-s} + E_s [\Phi_{it}] = E_s [\lambda_{it} P_t] \quad (12)$$

Then, the first-order condition for k_{it+1} implies:

$$E_s [\lambda_{it} P_t] = E_s \left[\lambda_{it+1} P_{t+1} \left((1 - \delta) + \frac{1}{P_{t+1}} \frac{\partial \pi_{it+1}(k_{it+1}, l_{it+1}, F(a(t+1), z(t)), M, L)}{\partial k_{it+1}} \right) \right] \quad (13)$$

2.2.1 Decision rules for capital and consumption

Capital and consumption The combination of (12) and (13) allows me to find the decision rules for d_{it}, k_{it+1} . Taking the perspective of period $s = t$, there are then two cases, either $\Phi_{it} > 0$ or $\Phi_{it} = 0$.

- **Case 1** When $\Phi_{it} = 0$, then k_{it+1} is optimally set such that:¹¹

$$1 = E_t \left[\lambda_{it+1} P_{t+1} \left((1 - \delta) + \frac{1}{P_{t+1}} \frac{\partial \pi_{it+1}(k_{it+1}, l_{it})}{\partial k_{it+1}} \right) \right] \quad (14)$$

And consumption $d_{it} = \frac{\pi_{it}(k_{it}, l_{it})}{P_t} - x_{it}$.

- **Case 2** When $\Phi_{it} > 0$, then $d_{it} = 0$ and the path of capital is determined by the budget constraint: $k_{it+1} = \frac{\pi_{it}(k_{it}, l_{it})}{P_t} + (1 - \delta)k_{it}$.

Output and markup The above decision rules also imply an output decision for both cases.

- **Case 1** When $\Phi_{it} = 0$, then firms in period t solve the following system of decision rules regarding period $t + 1$:

$$\begin{aligned} E_t \left[\lambda_{it+1} \frac{\partial \pi_{it+1}(k_{it+1}, l_{it})}{\partial k_{it+1}} \right] &= 1 - E_t [\lambda_{it+1} P_{t+1} (1 - \delta)] \\ \frac{\partial \pi_{it+1}(k_{it+1}, l_{it+1})}{\partial l_{it+1}} &= 0 \end{aligned}$$

- **Case 2:** When $\Phi_{it} > 0$, then the optimal labor choice l_{it+1} is chosen conditional on $k_{it+1} = \frac{\pi_{it}(k_{it}, l_{it})}{P_t} + (1 - \delta)k_{it}$.

Given the decision on k_{it+1}, l_{it+1} , the output y_{it+1} is determined due to the production function (1). Then, given (3), this determines the price p_{it+1} of the firm. This pricing decision simultaneously implies a decision on the markup in equation (9), given the firm's marginal cost.

2.3 Steady state equilibrium

An equilibrium consists of a set of prices P_t, w_t, p_{it} , a set of consumption $d_{it}(a_{it+1}, z_{it}, F(a(t+1), z(t)))$, capital $k_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)))$ and labor $l_{it}(a_{it}, z_{it-1}, F(a(t), z(t-1)))$ decisions by firm-owners and consumption by workers $\frac{w_t}{P_t} L$ that satisfy

- the labor market clearing condition

$$L = \sum_{i=1}^M l_{it} \quad (15)$$

- the goods market clearing condition

¹¹In case $E_t[\lambda_{t+1} P_{t+1}] = \beta$, i.e. when $E_t[\Phi_{t+1}] = 0$, then (14) simplifies to $\frac{\partial \pi_{it+1}(k_{it+1}, l_{it})}{\partial k_{it+1}} = P_{t+1} \left(\frac{1}{\beta} + \delta - 1 \right)$.

$$Q_t = \sum_{i=1}^M (x_{it} + d_{it}) + \int_{l \in L} c_{it} dl \quad (16)$$

- the optimality conditions (11), (13) for each firm i , conditional on the choices of l_{jt}, k_{jt} of all firms $j \neq i$.
- market-clearing for each variety i : $y_{it} = q_{it}$, satisfying (3)
- the equalized budget constraint $P_t(k_{it+1} + d_{it}) = z_{it}$, and the financial constraint $d_{it} \geq 0$.

To solve this equilibrium, I can pick as numeraire $w_t = 1$, and P_t is a function of the individual prices as in (4). Next, y_{it} is determined by k_{it}, l_{it}, a_{it} , where a_{it} is exogenous. Satisfying (3) implies that p_{it} is given by choice of y_{it} . Finally, l_{it}, k_{it}, d_{it} are determined by (11), (13) and the budget constraint (5), as explained in section 2.2.1. Since there are M firms, this then is a system of $M \times 3$ equations with $M \times 3$ unknowns.

A *steady state equilibrium* is an equilibrium that satisfies for all t ¹²:

$$\begin{aligned} K_t &= K, \\ \frac{P_t}{w_t} &= \frac{P}{w}, \\ F(a(t+1), z(t)) &= F(a', z) \end{aligned} \quad (17)$$

A first implication of this definition of the steady state, is that $H(a(t), k(t)) = H(a, k)$, i.e. the joint distribution of productivities and capital will be stable. The reason is that capital choice is determined by $F(a(t+1), z(t))$: $k_{it+1}(a_{it+1}, z_{it}, F(a(t+1), z(t)))$. A second implication is that aggregate output will be stable as well: $Q_t = Q$.

2.4 Analysis of the steady state

Section 2.3 implies that in steady state each firm's decisions depend on $F(a+1, z)$. In this joint distribution $F(a+1, z)$, the distribution of productivities is determined by its exogenous stochastic process. Hence, it is the distribution of wealth that is endogenous in $F(a+1, z)$, and which requires analysis. Since wealth z is a function of capital, I start by examining $H(a, k)$, the joint distribution of productivities and capital in steady state. Later, I will then link $H(a, k)$ to $F(a+1, z)$. To understand the distribution of capital in steady state, I will start by characterizing the firm's decision rules for capital and labor in steady state.

2.4.1 Labor and capital decisions in steady state

It will be convenient to characterize the solution to the firm's optimization problem by taking the perspective of the cost-minimization problem given the optimal markup characterized in

¹² Moll (2014) employs a similar definition of a steady state equilibrium.

(9).¹³ As such, the cost-minimization problem implies the following optimal labor demand in steady state:

$$l_{it} = \left(\frac{(1-\alpha)P}{\mu_{it}} \frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} a_{it}^{\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \quad (18)$$

As is clear from section 2.2.1, there are then two cases for the firm's capital choice: either $\Phi_{it} = 0$, or $\Phi_{it} > 0$.

Unconstrained firms First consider the case where a firm has $\Phi_{it} = 0$. In that case, the optimality condition in (13), together with (18) implies that

$$k_{it}^* = \mu_{it}^{\frac{1}{\eta-1}} a_{it}^{\frac{\eta}{1-\eta}} \frac{Q}{M} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \left(\frac{\alpha}{r_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \quad (19)$$

where $r_{it} \equiv \left(\frac{1}{\beta} + \delta - 1 \right) + \xi_{it}$.¹⁴

Constrained firms When the financial constraint binds, i.e. $\Phi_{it} > 0$. Capital grows according to the budget constraint. Specifically, after solving for the expression for revenue, one finds that:

$$k_{it+1} = (1-\delta)k_{it} + \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \left(\frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} a_{it}^{\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \quad (20)$$

2.4.2 Distribution and dynamics for firm-level capital

Given the expressions for k_{it}^* , and the path for capital of constrained firms in (20), I now characterize $H(a, k)$. First, consider the firms with $a_{it} = a_L$. In steady state, these firms cannot have $\Phi_{it} > 0$ ¹⁵, and therefore these firms have $k_{it} = k_L^*$, the optimal level of k_{it} for low productivity firms. Note that $k_{it}(a_L) > k_L^*$ violates the firm's optimality conditions, as firms consume any capital in excess of k_L^* , and thereby satisfy the decision rule for capital in equation (19).

Second, there are the firms with $a_{it} = a_H$. For these firms, either $\Phi_{it} = 0$, or $\Phi_{it} > 0$. When $\Phi_{it} = 0$, then these firms have $k_{it} = k_H^*$. When $\Phi_{it} > 0$, then $k_{it} = G_{\tau} k_L^*$, where $\tau = t - s$,

$$G_{\tau} \equiv \prod_{r=s}^{s+\tau} (1 + g_r) \quad (21)$$

$$s = \max r \text{ s.t. } a_{ir+1} = a_H \& a_{ir} = a_L$$

¹³Jaimovich (2007) also employs the cost-minimization approach to characterize the solution to the firm problem, and as such, the optimality conditions are closely related to the ones found in that paper.

¹⁴When $E_t[\Phi_{t+1}] = 0$, then $\xi_{it} = 0$, otherwise $\xi_{it} > 0$.

¹⁵Suppose this is not the case and there is at least one firm with $a_{it} = a_L \& \Phi_{it} > 0$. Then for all firms i with $a_{it} = a_L \& \Phi_{it} > 0$, $k_{it+1}(a_{it+1}, z_{it}, F(a+1, z)) > k_{it}$. Since these firms' This then violates the property of the steady state that $F(a(t+1), k(t)) = F(a', z)$.

$$g_r = \frac{k_{ir+1}}{k_{ir}} - 1$$

In words, k_{it} is determined by the cumulative capital growth G_τ since the firm's most recent positive productivity shock. In steady state, $G_{it,s}$ will be independent of the precise t, s and therefore I adjust notation to $G_{it,s} = G_\tau$:

Capital of unconstrained firms Following (19), the optimal values for capital k_L^*, k_H^* are:

$$\begin{aligned} k_L^* &= \left(\frac{a_L^\eta}{\mu_L}\right)^{\frac{1}{1-\eta}} \left(\frac{\alpha}{r_L}\right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{P(1-\alpha)}{w}\right)^{\frac{\eta-\alpha\eta}{1-\eta}} \frac{Q}{M} \\ k_H^* &= \left(\frac{a_H^\eta}{\mu_H}\right)^{\frac{1}{1-\eta}} \left(\frac{\alpha}{r_H}\right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{P(1-\alpha)}{w}\right)^{\frac{\eta-\alpha\eta}{1-\eta}} \frac{Q}{M} \end{aligned} \quad (22)$$

Where μ_L, μ_H , characterized further in section 2.4.3, are the optimal level of markups for the respective firms. Furthermore, $r_H = \frac{1}{\beta} + \delta - 1$ since $E_t[\Phi_{it}] = 0$ for all firms with $a_{it} = a_H$ and $\Phi_{it} = 0$. Next, r_L is the value for r_{it} for all firms with $a_{it} = a_L$.

Lemma 2.1. *Steady state $H(a, k)$ is determined by:*

- $a_i = a_L$, then $k_i = k_L^*$
- $a_i = a_H$ then $\forall i$ with $\tau = t - s$, where $s = \max r$ s.t. $a_{ir+1} = a_H$ & $a_{ir} = a_L$:
 - if $\Phi_\tau = 0$, then $k_{i\tau} = k_H^*$
 - if $\Phi_\tau > 0$, then $k_{i\tau} = G_\tau k_L^*$

Since for firms with $a_{it} = a_H$, the level of capital depends on G_τ , the value of Φ_{it} also depends on it: $\Phi_{it} = \Phi_\tau$.

2.4.3 Distribution of markups

Now, I characterize the distribution of markups. First, the markups for the unconstrained firms:

$$\begin{aligned} \mu_L(a_L, k_L^*, H(a, k), M) &\equiv \frac{1 - M^{\eta-1} \eta \frac{(a_L(k_L^*))^\alpha (l_L^*)^{1-\alpha} \eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(a_L(k_L^*))^\alpha (l_L^*)^{1-\alpha} \eta}{Q^\eta}\right)} \\ \mu_H(a_H, k_H^*, H(a, k), M) &\equiv \frac{1 - M^{\eta-1} \eta \frac{(a_H(k_H^*))^\alpha (l_H^*)^{1-\alpha} \eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(a_H(k_H^*))^\alpha (l_H^*)^{1-\alpha} \eta}{Q^\eta}\right)} \end{aligned} \quad (23)$$

Constrained firms For constrained firms, we know that $k_{it} = G_\tau k_L^*$, and the markup for these firms can be written as:

$$\mu_\tau(a_H, G_\tau k_L^*, H(a, k), M) \equiv \frac{1 - M^{\eta-1} \eta \frac{(y(a_H, G_\tau k_L^*), F(a, k))^\eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(y(a_H, G_\tau k_L^*), F(a, k))^\eta}{Q^\eta}\right)} \quad (24)$$

Together (23), (24), characterize the distribution of markups.

2.4.4 TFP and capital wedges

I now characterize TFP . In appendix A.1, I derive equation (53), which is the explicit function for TFP . It is clear from that equation, that TFP is a function of the joint distribution of productivities, markups and capital wedges ω_{it} . These capital wedges ω_{it} are implicitly defined in the following way:

$$k_{it} = \left(\frac{a_{it}^\eta}{\mu_{it}} \right)^{\frac{1}{1-\eta}} \left(\frac{\alpha}{\omega_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{P_t(1-\alpha)}{w_t} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \frac{Q_t}{M} \quad (25)$$

where $\omega_{it} = r_{it}$ if the firm is unconstrained, and $\omega_{it} > r_{it}$ otherwise.

Since the capital wedges are a function of a_{it}, k_{it} , I can use Lemma 2.1 and equations (23),(24), to characterize TFP as:

$$TFP = F_{TFP}(H(a, k), M) \quad (26)$$

Distribution of capital wedges In the next section, I will be analyzing comparative statics on TFP . To this end, it will be useful to more closely examine the properties of the capital wedges ω_{it} . First, since for unconstrained firms $\omega_{it} = r_{it}$, for firms with $a_{it} = a_L$, $\omega_{it} = r_L$. For unconstrained firms with $a_{it} = a_H$, $\omega_{it} = r_H$. Note that $r_H = \frac{1}{\beta} + \delta - 1$, since for these firms $E_t[\Phi_{t+1}] = 0$. Then, for constrained firms, I combine equations (22) and (25), to express the capital wedge for any period $t - s$:¹⁶

$$\omega_\tau = G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^\eta \mu_L}{a_L^\eta \mu_\tau} \right]^{\frac{1}{1+\alpha\eta-\eta}} r_L \quad (27)$$

Note that: $\max_t \omega_\tau = \omega_1 = G_1^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^\eta \mu_L}{a_L^\eta \mu_1} \right]^{\frac{1}{1+\alpha\eta-\eta}} r_L$. Hence the distribution of ω_τ for firms with $a_{it} = a_H$, has a range $[r_H, \omega_1]$, and further depends on the endogenous variables G_τ, μ_τ .

Lemma 2.2. *In steady state, the distribution of capital wedges is:*

- For firms with $a_{it} = a_L$, $\omega_{it} = r_L$
- For firms with $a_{it} = a_H$:
 - When $\Phi_\tau = 0$, $\omega_{it} = \frac{1}{\beta} + \delta - 1$
 - When $\Phi_\tau > 0$, $\omega_\tau(G_\tau, \mu_\tau) = G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^\eta \mu_L}{a_L^\eta \mu_\tau} \right]^{\frac{1}{1+\alpha\eta-\eta}} r_L$

¹⁶The expression is found after simplifying $\omega_{it} = \alpha(G_{it,s} k_L^*)^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{Q_t}{M} \right)^{1-\eta} \left(\frac{P_t(1-\alpha)}{w_t} \right)^{\eta-\alpha\eta} \right]^{\frac{1}{1+\alpha\eta-\eta}}$

2.4.5 Aggregates for output and capital

Aggregate output In appendix A.1, I show that

$$Q = TFPK^\alpha L^{1-\alpha} \quad (28)$$

where TFP is aggregate productivity and K is aggregate capital.

Aggregate capital Given Lemma 2.1, aggregate capital $K_t = \sum_{i=1}^M k_{it}$ can in steady state be expressed as:

$$K = M \left[Prob(a_{it} = a_L)k_L^* + \sum_{\tau=1}^{\infty} Prob(a_{it} = a_H \& s = t - \tau)G_\tau k_L^* \right]$$

After substituting in the value for k_L^* , and using $Q = TFPK^\alpha L^{1-\alpha}$. We find:¹⁷

$$K^{1-\alpha} = TFP L^{1-\alpha} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \alpha^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{a_L^\eta}{\mu_L r_L^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \left[Prob(a_{it} = a_L) + \sum_{\tau=1}^{\infty} Prob(a_{it} = a_H \& s = t - \tau)G_\tau \right] \quad (29)$$

2.5 Labor Market clearing

Since there are only two markets, by Walras' Law, general equilibrium is realized when the labor market clears. Labor demand, given in equation (18), from all firms has to equal labor supply L :

$$L = \sum_{i=1}^M \left(\frac{(1-\alpha)P}{\mu_{it}} \frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} a_{it}^\eta k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

In appendix A.2, this equation is derived further. Then, notice that labor market clearing is realized for the following $\frac{P}{w}$:

$$\frac{P}{w} = \left(\frac{L}{K} \right)^\alpha \frac{\Omega^{\eta-\alpha\eta-1}}{(1-\alpha) \left(\frac{TFP}{M} \right)^{1-\eta}} \quad (30)$$

¹⁷ Specifically:

$$K = Q \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \alpha^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{a_L^\eta}{\mu_L r_L^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \left[Prob(a_{it} = a_L) + \sum_{\tau=1}^{\infty} Prob(a_{it} = a_H \& s = t - \tau)G_\tau \right]$$

where $\Omega \equiv \left[\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right]$. Like TFP , Ω is a function of

the joint distribution of productivities, markups and capital. In a context with monopolistic competition, i.e. without variable markups, this condition would not exist.

In short, the above implies that the labor market clearing equation can be written as:

$$\frac{P}{w} = F_L(M, L, K, TFP, \Omega) \quad (31)$$

2.5.1 Systems of Equations

In steady state, the following systems of equations will determine the nature of the equilibrium:

- The joint distribution of a_{it} , k_{it} , characterized in Lemma 2.1
- The distribution of markups μ_{it} , where

$$\mu_{it}(a_{it}, k_{it-1}, H(a, k), M, L)$$

- TFP , which depends on the joint distribution of a_{it} , k_{it} , μ_{it} , and which therefore can be characterized as:

$$TFP = F_{TFP}(H(a, k), M) \quad (32)$$

- Aggregate capital:

$$K^{1-\alpha} = TFP L^{1-\alpha} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \alpha^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{a_L^\eta}{\mu_L r_L^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \left[Prob(a_{it} = a_L) + \sum_{\tau=1}^{\infty} Prob(a_{it} = a_H \& s = t - \tau) G_\tau \right] \quad (33)$$

- The factor-price ratio, determined in the labor market equilibrium:

$$\frac{P}{w} = F_L(M, L, K, TFP, \Omega) \quad (34)$$

- $\Omega \equiv \left[\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right]$

In the comparative statics exercise that now follows, I describe how the steady state variables change with M . A crucial role there will be played by the comparative statics on G_τ , which codetermines the distribution of capital.

2.6 Comparative statics on competition

In the theoretical appendix sections, I demonstrate the following proposition on the comparative statics for M :

Proposition 2.3. *For unconstrained firm-types L, H , and for constrained firms in period $\tau > 0$:*

- *Markup levels fall with M :*

$$\frac{\partial \mu_L}{\partial M} < 0; \frac{\partial \mu_H}{\partial M} < 0; \frac{\partial \mu_\tau}{\partial M} \leq 0$$

- *Markup dispersion falls with M :*

$$\frac{\partial \frac{\mu_H}{\mu_L}}{\partial M} < 0; \frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} \leq 0$$

- *Capital wedges worsen with M :*

$$\frac{\partial \omega_\tau}{\partial M} \geq 0$$

$$\text{and } (\Phi_\tau > 0) \implies \left(\frac{\partial \omega_\tau}{\partial M} > 0 \right)$$

The proposition demonstrates the dual role of competition in an environment with both variable markups and financial constraints. On the one hand, markup misallocation improves, since both markup levels and markup dispersion fall with M . On the other hand, misallocation due to capital wedges worsens due to competition. Since the latter effect is absent in a setting without financial constraints while the former is not, the welfare gains from competition tend to be lower in a setting with financial constraints compared to a setting without financial constraints.

3 Data

The empirical analysis employs plant-level panel data from the Indian Annual Survey of Industries (ASI), for the period 1990-2011. The ASI sampling scheme consists of two components.¹⁸ One component is a census of all manufacturing establishments with more than 100 employees, while a second component samples, with a certain probability, each formally registered establishment with less than 100 employees. All establishments with more than 20 workers (10 workers if the establishment uses electricity) are required to be formally registered. A detailed description of the ASI data, and its unbalanced panel structure, is provided by [Bollard et al. \(2013\)](#).¹⁹

¹⁸The particulars provided here hold for the majority of the sample years. [Bollard et al. \(2013\)](#) provide a detailed description of the ASI sampling scheme.

¹⁹For the years 1998-2011, establishment identifiers are provided by the Indian Statistical Office. For the pre-1998 years, I use the panel-identifiers employed by [Allcott et al. \(2014\)](#), which were generously made available by Hunt Allcott.

In the first part of the empirical exercise, I will be exploiting variation across sectors and geographical units in India. Here, sectors are defined as 3-digit sectors based on India's 1987 National Industrial Classification (NIC). The geographical units in the data are either states or union territories. For reasons of convenience, I will be referring to both geographical units as states in the remainder of this paper.²⁰

3.1 Variable definitions

The main baseline variables are capital K_{irst} , labor L_{irst} , materials M_{irst} and revenue S_{irst} , for plant i in state r and sector s in year t . Here, t stands for the financial year, and K_{it} is the book value of assets at the start of the financial year. The logarithm of a variable will be denoted in lower case.

This paper analyzes capital growth in relation to productivity volatility, age, and competition, and I now describe the construction of these main variables. A first main variable of interest is capital growth, which is measured as:

$$g(k_{irst}) = k_{irst+1} - k_{irst} \quad (35)$$

where K_{irst+1} is the book value of assets at the end of the financial year. A second variable is firm-level productivity, where I follow [Asker et al. \(2014\)](#) in the measurement. Specifically, I impose, as in the theory, that revenue takes a Cobb-Douglas form. Together with the assumption of cost-minimization these structural assumptions imply that productivity a_{it} can be measured as:

$$a_{it} = s_{irst} - \beta_s^K k_{it} - \beta_s^L l_{it} - \beta_s^M m_{it} \quad (36)$$

where s_{irst} is firm revenue and $\beta_s^L = \text{Median}_s \left[\frac{\text{wage bill}_{irst}}{S_{irst}} \right]$, $\beta_s^M = \text{Median}_s \left[\frac{M_{irst}}{S_{irst}} \right]$, $\beta_s^K = 1 - \beta_s^L - \beta_s^M$. In addition I also use a value-added measure of productivity:²¹

$$a_{irst}^{VA} = va_{irst} - \beta_s^{K,VA} k_{irst} - \beta_s^{L,VA} l_{irst}$$

with $\beta_s^{L,VA} = \text{Median}_s \left[\frac{\text{wage bill}_{irst}}{VA_{irst}} \right]$; $\beta_s^{K,VA} = 1 - \beta_s^{L,VA}$.²² Employing different productivity measures based on either gross revenue or value added serves as a primary robustness check. Since the measured elasticities for labor and capital are meaningfully different in the two measures, any sensitivity of the findings to the particular choice of output elasticities is substantially mitigated.

This is mainly a robustness check for different values of the cost shares, and empirically ends up putting more emphasis on the labor share than on the materials share.

Next, I employ a measure of marginal revenue product of capital (MRPK), where I again

²⁰I employ the concordance provided by the Indian Statistical Office to make the definitions of states consistent over time. This way, I have 35 "states" in my data.

²¹Where value added is measured as: $VA_{irst} = S_{irst} - M_{irst}$

²²To avoid sensitivity to outliers, the median is calculated at the 2-digit sector level.

follow [Asker et al. \(2014\)](#) by imposing Cobb-Douglas production functions, which implies that the marginal revenue product of capital takes the following form:

$$MRPK_{irst} = \ln(\beta_s^K) + s_{irst} - k_{irst} \quad (37)$$

Here as well, I employ a value-added measure for MRPK as well, as a leading robustness check:

$$MRPK_{irst}^{VA} = \ln(\beta_s^{K,VA}) + va_{irst} - k_{irst} \quad (38)$$

In the theoretical section, I showed that when M increases, the level of markup falls (appendix D). As such, the model features a close correlation between the markup levels and the degree of competition. This explains why the primary, inverse measure of competition at the state-sector-year level will be:

$$Median_{rst}[\ln \mu_{irst}]$$

where μ_{irst} is the firm-level markup. Intuitively, if competition decreases, firms are able to charge a higher markup and thereby increase their profitability. The measurement of the median markup follows the procedure outlined by [De Loecker and Warzynski \(2012\)](#), and is discussed in appendix H, which assumes firms have Cobb-Douglas production functions and minimize costs.

$$\mu_{irst} = \beta_s^L \frac{VA_{irst}}{w_{irst}L_{irst}} \quad (39)$$

where $w_{irst}L_{irst}$ is the wage bill. Intuitively, when firms spend a higher share of value added on the variable labor input, conditional on the output elasticity for labor, these firms are setting a lower markup.

4 Stylized facts

This section first validates the main assumptions of the model, and second, provides motivating evidence in support of a central market-level prediction of the model. The next section will then examine the firm-level predictions of the model.

4.1 Validation of model assumptions

In this subsection I provide stylized facts that provide support for the main assumptions of the model. These two conditions are first the relationship between productivity volatility and the dispersion in MRPK, and second, capital growth by young plants.

4.1.1 Productivity Volatility

First, I examine the relationship between productivity volatility and dispersion in MRPK. A central mechanism in the model is that financial constraints lead to firms exhibiting delayed adjustment of their capital levels to positive productivity shocks. [Asker et al. \(2014\)](#) show how in a setting with delayed adjustment of capital to productivity shocks, there is a positive relationship between the dispersion in MRPK and productivity volatility.²³ As such, documenting this positive relationship for the Indian manufacturing sector provides empirical support for the main mechanism of the model.

[Asker et al. \(2014\)](#) document that such a positive relationship is significantly present across sectors within multiple countries. However, they do not analyze this relationship for the Indian ASI data, which is the dataset for this paper's empirical analysis.²⁴ I again adopt the empirical measures employed by [Asker et al. \(2014\)](#), where the measure for dispersion in MRPK is here measured at the sector-year level:

$$\text{MRPK Dispersion} = \text{Std}_{st}(\text{MRPK}_{irst}) \quad (40)$$

And the empirical measure for productivity volatility is

$$\text{Productivity Volatility} = \text{Std}_{st}(a_{it} - a_{it-1}) \quad (41)$$

In [Figure 1](#), we see that there is a strong upward sloping relationship between productivity volatility and MRPK dispersion, for both the gross sales based measure, and for the value-added based measure. This empirical relationship corroborates the relevance of the theoretical model.²⁵

²³ [Asker et al. \(2014\)](#) provide a model with capital adjustment costs that predicts this empirical pattern. The main difference with a collateral constraint, is that the delayed adjustment only occurs after positive productivity shocks. Note that [Asker et al. \(2014\)](#) do not provide evidence for the fact that this relationship is driven by adjustment costs. Moreover, while the relationship in [1](#) is consistent with a model centered around adjustment costs, the evidence later in the next sections, centered around the relation between capital convergence and competition, is not captured by an explanation based on adjustment costs.

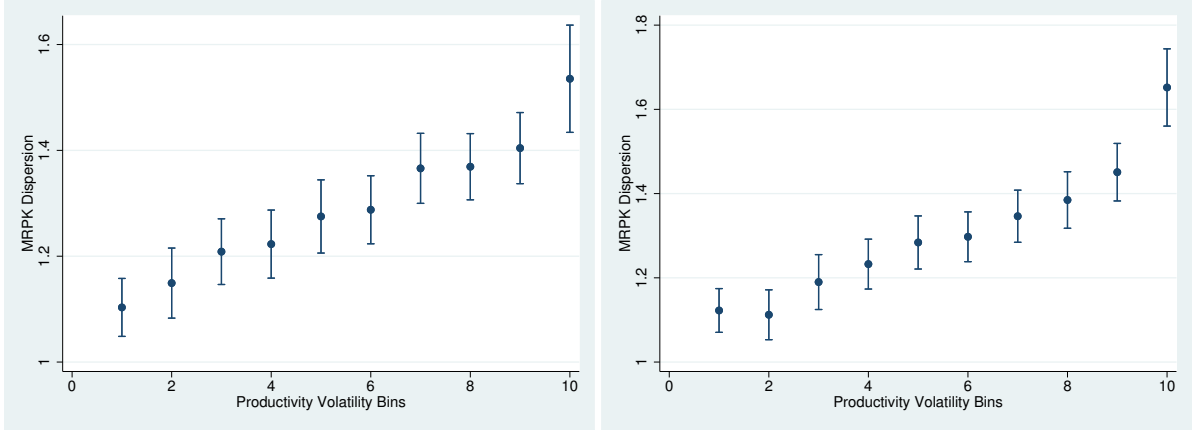
²⁴ [Asker et al. \(2014\)](#) document that this relationship holds within the Prowess dataset in India. Since Prowess features firms registered on the stock market, the analysis here is a useful complement to their analysis

²⁵ In [appendix I.1](#), I follow [Asker et al. \(2014\)](#) by implementing variations on their plant-level robustness test for this relationship between MRPK dispersion and productivity volatility.

Figure 1: Productivity volatility and MRPK dispersion

(a) Gross revenue based

(b) Value-added based



For the analysis in this figure, the sample is split into 10 deciles of $Std_{st}(a_{it} - a_{it-1})$. Then I run the regression $Std_{st}(MRPK_{irst}) = \sum_{i=1}^{10} \gamma_i 1(Decile\ i) + \varepsilon_{st}$, and plot the values for the coefficients and 95% confidence intervals of γ_i .

4.1.2 Age and Capital Growth

In an extension of the model, described in appendix G, I assume that firms are born with suboptimally low levels of capital and transition to an optimal level of capital at the start of their life-time. This way, the birth rate of undercapitalized firms can be a source of capital misallocation in a setting with financial constraints. Here, I examine whether it is empirically true that newborn exhibit higher capital growth rates than older firms. The existing empirical literature provides extensive support for this stylized fact (Evans, 1987; Geurts and Van Biesebroeck, 2014; Haltiwanger et al., 2013), and I now test its validity for the Indian manufacturing sector.²⁶

In specifications 1-4 in Table 1, we see that the growth rate of capital is increasing with $1/age$, and therefore decreasing with age. This pattern is confirmed in the non-parametric specifications, as capital growth is higher for firms not older than 5 or younger than 10 years.

²⁶Another relevant stylized fact relates to within-cohort capital misallocation. If there is heterogeneity across firms in capital or productivity levels at the time of their birth, translating immediately in heterogeneity in MRPK, the model would predict this dispersion in MRPK to decline with age. This pattern is observed in Table A.2, and discussed in appendix I.

Table 1: Capital growth as a Function of Age

	Plant-level Capital Growth $g(k_{irst})$							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\frac{1}{age_{irst}}$	0.0814** (0.00412)	0.140** (0.00569)						
$\ln(\frac{1}{age_{irst}})$			0.0136** (0.00108)	0.0357** (0.00169)				
$1(age_{irst} \leq 5)$					0.0597** (0.00210)	0.0576** (0.00281)		
$1(age_{irst} < 10)$							0.0369** (0.00190)	0.0306** (0.00259)
State-sector-year FE	Yes	No	Yes	No	Yes	No	Yes	No
Plant FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	644922	644922	644922	644922	658886	658886	658886	658886

Standard errors, clustered at the plant level, in parentheses (* $p < 0.05$, ** $p < 0.01$).

Indices are i for plant, r for state, s for sector and t for year.

$g(k_{irst}) = \ln K_{irst+1} - \ln K_{irst}$, where capital is the book value of assets, measured at the start (t) and end ($t + 1$) of the year.

4.2 Correlation between Competition and Misallocation

The model predicts that capital misallocation might worsen when the degree of competition is more intense. To provide suggestive evidence for this prediction, I run the following regression:

$$Std_{rst}(MRPK_{irst}) = \alpha_s + \gamma_t + \zeta_r + \beta Median_{rst}[\ln \mu_{irst}] + \epsilon_{rst} \quad (42)$$

In this specification I use $Median_{rst}[\ln \mu_{irst}]$ as the inverse measure of competition, α_s are sector fixed effects, γ_t are year fixed effects and ζ_r are state fixed effects. To allow for different sources of variation, I also run this specification without γ_t, ζ_r . I always include α_s to eliminate variation arising from the measurement of β_s^K , the output elasticity which is measured at the sector level.

Results Table 2 provides suggestive evidence for the main empirical relationship predicted by the model. First we notice that $Std_{rst}(MRPK_{irst})$ is consistently negatively related to the median markup in a state-sector-year observation. This holds for both measures of $MRPK$, and it holds regardless of the specific set of fixed effects.²⁷

²⁷One might be worried about a mechanical correlation between the level of μ_{irst-1} and $Std_{rst}(MRPK_{irst})$. Note, however, that this would imply a positive correlation, while the table demonstrates a persistently negative correlation.

Table 2: MRPK Dispersion and Competition

	$Std_{rst}(MRPK_{irst}(Gross\ Revenue))$				$Std_{rst}(MRPK_{irst}(Value\ Added))$			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$Median_{rst-1}[\ln \mu_{irst-1}]$	-0.0547** (0.0102)	-0.0494** (0.0101)	-0.0371** (0.0102)	-0.0353** (0.0101)	-0.0501** (0.00977)	-0.0447** (0.00972)	-0.0376** (0.0101)	-0.0353** (0.00997)
Constant	1.306** (0.00487)	1.236** (0.0125)	1.257** (0.0329)	1.228** (0.0347)	1.321** (0.00465)	1.438** (0.0291)	1.336** (0.0362)	1.477** (0.0457)
Year FE	No	Yes	No	Yes	No	Yes	No	Yes
State FE	No	No	Yes	Yes	No	No	Yes	Yes
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	19951	19951	19951	19951	19570	19570	19570	19570

Standard errors, clustered at the state-sector level, in parentheses (* $p < 0.05$, ** $p < 0.01$).

Indices are i for plant, r for state, s for sector and t for year. Hence, observations are at the state-sector-year level.

Specifications 1-4 measure MRPK based on gross revenue, and specifications 5-8 based on value added.

The next empirical section will investigate the underlying micro-dynamics for the correlation presented in Table 2. Specifically, we will investigate whether the model predictions on firm-level behavior are validated by the data.

5 Competition and firm-level capital convergence

In this section, I test the validity of the model at the firm level. To this end, I first derive empirical predictions of the model, which I then test with on the ASI panel data.

5.1 Empirical predictions

The model describes how competition affects misallocation by slowing down the speed of capital convergence. I now describe how this results in empirical predictions for convergence in marginal revenue product of capital (MRPK). Subsequently, I explain how a related empirical prediction applies to capital growth for young plants.

Convergence and productivity volatility In the model with productivity volatility, firms choose to grow their capital stock in response to positive productivity shocks. Specifically, when a positive productivity shock implies that a firm cannot satisfy its unconstrained first-order condition in (14), this implies that $MRPK_{it}^* < MRPK_{it}$. Here $MRPK_{it}$ is a firm's actual MRPK, and $MRPK_{it}^*$ is the optimal MRPK from the unconstrained solution. In the model, the speed at which a firm converges to $MRPK_{it}^*$ depends on the degree of competition M . Specifically, lowering M leads to faster MRPK convergence. Hence, this is a first empirical prediction of the model, namely that MRPK convergence is faster under lower levels of competition. In the next subsection, I will describe how I measure competition and how I measure $MRPK_{it}^*$.

An additional prediction of the model relies on how technological differences across sectors translate into differential impact of competition on the speed of convergence. Here, the intuition is that for sectors with higher levels of financial dependence, which arise from differences in capital shares α across sectors, changes in the level of sector-level competition, and

therefore changes in the level of markups, have a stronger impact on the rate of capital growth. Formally, related to equation 60, I intend to show that (in progress):

$$\frac{\partial^2 g \left(\mu_{it}, \frac{P_t}{w_t} | G_{it,s} \right)}{\partial \alpha \partial M} < 0$$

Young plants In appendix section G I show that a model with birth of newborn firms is essentially isomorphic to the baseline model. As such, it has analogous implications for the rate of capital convergence as the model with productivity volatility, namely competition slows down capital convergence.

5.2 Econometrics

To test the predictions of the model, I exploit variation in the median markup at the state-sector-year level. As such, the variation in competition, measured by the markup, is plausibly exogenous to the individual firm.

MRPK convergence As discussed in the previous subsection, the main prediction relates to the speed of MRPK convergence. Specifically, I will test if the speed of MRPK convergence decreases with the degree of competition. To this end, I implement the following auto-regressive specification²⁸

$$MRPK_{irst} = \alpha_{irs} + \rho_0 MRPK_{irst-1} + \rho_1 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] + \beta X_{irst} + \gamma_t + \varepsilon_{irst} \quad (43)$$

The main coefficient of interest in this specification is ρ_1 . This coefficient estimates how the speed of convergence changes as a function of $Median_{rst-1}[\ln \mu_{irst-1}]$, the inverse measure for the degree of competition.²⁹ To build intuition for this estimation strategy, first consider the case when $\rho_0 = \rho_1 = 0$. In that case, plants exhibit immediate convergence to the empirical counterpart of $MRPK_{irst}^*$, i.e. $E[MRPK_{irst} | (\rho_0 = \rho_1 = 0)] = MRPK_{irst}^*$, regardless of $MRPK_{irst-1}$. In specification (43), the empirical proxy for $MRPK_{irst}^*$ is $\alpha_{is} + \beta X_{irst} + \gamma_t$, and below I discuss the choice of empirical proxy in more detail.

In practice, we will find that $0 < \rho_0 + \rho_1 < 1$ and $\rho_0 > \rho_1$, such that on average firms experience a delayed adjustment to $MRPK_{irst}^*$. Importantly, $\rho_1 < 0$ will indicate that the speed of MRPK convergence increases with $Median_{rst-1}[\ln \mu_{irst-1}]$, as long as:

$$|\rho_0 + \rho_1 * Median_{rst-1}[\ln \mu_{irst-1}]| < \rho_0$$

I will employ two main empirical proxies for $MRPK_{irst}^*$. A first specification is $MRPK_{irst}^* = \alpha_{irs} + \beta X_{irst} + \gamma_t$, as indicated in specification 43, and a second measure is $MRPK_{irst}^* =$

²⁸Since $MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}]$ varies at the plant-level, standard errors will be clustered at the plant level in specifications 43, 44.

²⁹In the regressions, $Median_{rst-1}[\ln \mu_{irst-1}]$ is demeaned across state-sector-year observations.

$\alpha_{irs} + \alpha_{rst} + \beta X_{irst}$. Here, α_{irs} is a firm-fixed effect, α_{rst} is a state-sector-year fixed effect, γ_t is a year fixed effect, and X_{irst} is a set of control variables. It is ambiguous which of the two specifications for $MRPK_{irst}^*$ is preferred, as it depends on whether year-by-year fluctuations at the state-sector level, as captured by α_{rst} , influence $MRPK_{irst}^*$ or not.³⁰ Throughout, the vector of control variables X_{irst} consists of a quadratic polynomial in age_{irst} .

In addition to the general prediction on MRPK convergence, the model suggests that firms more dependent on finance benefit more from an increase in profitability due to higher markups. Therefore, we augment the earlier specifications with the interaction predicted by the theory:

$$\begin{aligned} MRPK_{irst} = & \alpha_{irs} + \rho_0 MRPK_{irst-1} + \rho_1 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] \\ & + \rho_2 MRPK_{irst-1} * Fin Dep_s + \rho_3 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] * Fin Dep_s \\ & + \beta X_{irst} + \gamma_t + \varepsilon_{irst} \end{aligned} \quad (44)$$

Where $Fin Dep_s$ is the **Rajan and Zingales (1998)** measure for the sector-level financial dependence. Specifically, $Fin Dep_s = \frac{Capital Expenditures_s - Cash Flow_s}{Capital Expenditures_s}$ for US industries in the 1980's (ISIC Rev. 2).³¹ As explained by **Rajan and Zingales (1998)**, the identifying assumption here is that $Fin Dep_s$ captures the share of external finance in a firm's investments in a setting with close to perfectly developed financial markets, i.e. the US. In a setting with less developed financial markets, financial constraints then become especially binding in sectors with high levels of $Fin Dep_s$.

Young plants In addition to the MRPK convergence prediction, a model extension also predicts that competition matters for the capital growth rate for young plants. Therefore, I run the following regression:³²

$$g(k_{irst}) = \alpha_{rst} + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \varepsilon_{irst} \quad (45)$$

Where I will consider three different proxies for a firm being young: $\ln(1/age_{irst})$, $1(age_{irst} \leq 5)$, $1(age_{irst} < 10)$. I will also examine the analogue of specification 44, to examine the heterogeneous effect of $Median_{rst}[\ln(\mu_{irst-1})]$ for young firms' capital growth in sectors with higher

³⁰To gain further understanding of the estimation procedure, note that typically a_{rst} varies over time, implying that state-sector fluctuations are correlated with $MRPK_{irst}$. The structural question is then to which extent these fluctuations influence $MRPK_{irst+1}^*$, i.e. to which extent α_{rst} is a component of $MRPK_{irst+1}^*$. Since the answer to that question is theoretically ambiguous, I perform estimations both with and without α_{rst} in the specification.

³¹I use the ISIC Rev.2 sector-definitions because these match closely with India's NIC 1987 sector-definitions. The concordance between ISIC Rev.2 and NIC 1987 is provided by the Indian Statistical Office.

³²For specifications 45, 48 standard errors will be clustered at the sector level.

levels of financial dependence³³:

$$g(k_{irst}) = \alpha_{rst} + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} * Fin Dep_s + \varepsilon_{irst} \quad (48)$$

The next subsection discusses the estimation results for the above specifications.

5.3 Results

MRPK Convergence Table 3 provides the estimation results for equation 43 and 44, which confirm the theoretical predictions of the model. First, across all specifications, in Table 3, the estimate for ρ_0 is both significantly different from 0 and significantly different from 1. This is consistent with the theory, which states that there is convergence to $MRPK_{irst}^*$, i.e. $|\rho_0| < 1$, and predicts that convergence is not immediate ($\rho \neq 0$) due to financial constraints. Also note that both within the gross revenue and within the value-added measure for $MRPK$, the coefficient estimate for ρ_0 is fairly stable.³⁴

In terms of the role of competition, I find that the speed of convergence always increases with $Median_{rst}[\ln(\mu_{irst-1})]$. In the baseline specifications (1,2,5,6), the coefficient on ρ_0 is always negative and strongly statistically significant ($p < 0.01$). This confirms the qualitative prediction of the model that the speed of convergence slows down with competition. To understand the magnitude of the estimates, examine the difference in convergence speed going from a state-sector-year observation whose median markup is in the 10th percentile of median markups, to an observation with median markup in the 90th percentile. For the baseline specification, this magnitude is largest in the specifications with both plant and state-sector-year fixed effects. For instance, in specification (2), the described comparison entails a reduction in $\rho_0 + \rho_1 * Median_{rst}[\ln(\mu_{irst-1})]$ of 0.0639, which is 19.5% of the point estimate of ρ_0 .

In addition to the average effect of competition on MRPK convergence, I also test for heterogeneity along the degree of sectoral financial dependence in specifications (3,4,7,8). As expected, the coefficient ρ_3 , estimated on the triple interaction term, is always negative. Moreover, this coefficient estimate is strongly statistically significant in specifications (3,4,7).³⁵ A related finding is that for these specifications, the magnitude of the influence of the median markup is highest in sectors with higher financial dependence. For instance, consider a sector

³³In addition to specifications 45, 48, I will also estimate:

$$g(k)_{irst} = \alpha_{irs} + \gamma_t + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] + \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \varepsilon_{irst} \quad (46)$$

$$g(k_{irst}) = \alpha_{irs} + \gamma_t + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] + \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \beta_4 Median_{rst}[\ln(\mu_{irst-1})] * Fin Dep_s + \beta_5 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} * Fin Dep_s + \varepsilon_{irst} \quad (47)$$

For these two specifications, standard errors will be clustered at the plant-level.

³⁴Since gross revenue and value-added are structurally different, similar magnitudes of ρ_0 across these two measures is not expected.

³⁵The exception is specification (8), where the magnitude of the point estimate is comparable to those in the other specifications, although the estimate is not statistically significant.

with a level of financial dependence at the 90th percentile in specification (4). For firms in such a sector, going from a state-sector-year observation whose median markup is in the 10th percentile of median markups, to an observation with median markup in the 90th percentile of median markups, reduces $\rho_0 + ((\rho_1 + \rho_3) * Median_{rst}[\ln(\mu_{irst-1})])$ by 0.0889.

Further evidence In appendix K, I provide further evidence on the speed of convergence as a function of competition by analyzing convergence of the capital-labor ratio. In that appendix section, the data again confirms the predictions of the model.

Young Plants Table 4 displays the estimation results for specifications 45, 46, 47, 48. In general, capital growth for young firms increases with $Median_{rst}[\ln(\mu_{irst-1})]$, across all three measures for a firm being young, and this result is statistically significant in columns 1-6.³⁶ The magnitude of the point estimates is substantial. Consider again the counterfactual of moving from a state-sector-year observation whose median markup is in the 10th percentile of median markups, to an observation with median markup in the 90th percentile. For this counterfactual, the average capital growth rate increases by 3.6 percentage points for a firm less than 5 years old (specification 1).

Specifications 7-12 analyze the heterogeneous effect of competition as a function of the degree of financial dependence. Across all specifications, the estimates are consistent with the theory. The heterogeneous effect is not generally statistically significant, but it is significant in specifications 7 and 10 which focus on firms with $age_{irst} \leq 5$. For these specifications, the counterfactual of changing the median markup from the 10th to the 90th percentile within a sector that is at the 90th percentile of financial dependence has the substantial impact of more than 7 percentage points. This suggests that the interaction of competition with financial dependence is particularly salient for firms less than 5 years old, while still being potentially salient for slightly older firms.

The conclusion from tables 3 and 4 is that the data confirm that competition slows down capital convergence, both for general MRPK convergence, and for capital growth for young firms. Moreover, competition appears especially salient for capital convergence in sectors with higher levels of financial dependence.

³⁶One exception is specification (2), where the coefficient on $Median_{rst}[\ln \mu_{irst-1}] * 1(age < 10)$ is borderline significant at $p=0.084$.

Table 3: Speed of MRPK convergence

	MRPK _{irst} (Gross Revenue (GR))			MRPK _{irst} (Value added (VA))					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
MRPK _{irst-1} (GR)	0.442** (0.00571)	0.327** (0.00563)	0.413** (0.00639)	0.305** (0.00772)					
MRPK _{irst-1} (GR) * Median _{rst-1} [ln μ _{irst-1}]	-0.00340** (0.00131)	-0.0339** (0.0139)	-0.000861 (0.00213)	0.00155 (0.0139)					
MRPK _{irst-1} (GR) * Fin Dep _s			0.00887 (0.00572)	0.0382* (0.0154)					
MRPK _{irst-1} (GR) * Median _{rst-1} [ln μ _{irst-1}] * Fin Dep _s			-0.0124** (0.00439)	-0.0634* (0.0271)					
MRPK _{irst-1} (VA)					0.296** (0.00527)	0.189** (0.00508)	0.279** (0.00613)	0.160** (0.00717)	
MRPK _{irst-1} (VA) * Median _{rst-1} [ln μ _{irst-1}]					-0.0103** (0.00195)	-0.0306** (0.0105)	-0.00522 (0.00306)	0.0000582 (0.0144)	
MRPK _{irst-1} (VA) * Fin Dep _s							0.0198** (0.00688)	0.0593** (0.0139)	
MRPK _{irst-1} (VA) * Median _{rst-1} [ln μ _{irst-1}] * Fin Dep _s							-0.0160** (0.00612)	-0.0229 (0.0252)	
Influence of Median_{rst-1}[ln μ_{irst-1}] on convergence speed:									
ρ ₁ * [90%ile[Median(ln μ)] - 10%ile[Median(ln μ)]]		-0.00641	-0.0639	-0.00162	0.00292	-0.0194	-0.0577	-0.00984	0.000109
[ρ ₁ + ρ ₃ * Fin Dep _s (90%ile)] * (90%ile[Median(ln μ)] - 10%ile[Median(ln μ)])				-0.0196	-0.0889			-0.0330	-0.0330
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	Yes	No	Yes	No
State-sector-year FE	No	Yes	No	No	Yes	No	Yes	No	Yes
Observations	238359	238359	196323	196323	196162	196162	162265	162265	162265

Standard errors, clustered at the plant-level, in parentheses (* p < 0.05, ** p < 0.01). Variables MRPK_{irst} (GR), MRPK_{irst} (VA) for MRPK (marginal revenue product of capital) are defined in section 3.1. The inverse measure for competition, Median_{irst}[ln μ_{irst}], is demeaned within sectors. All specifications include a quadratic polynomial of firm age as control variables.

90%ile[Median(ln μ)] and 10%ile[Median(ln μ)] are the respective values for the 90th and the 10th percentile of Median_{irst-1}[ln μ_{irst-1}] across state-sector-year observations. This way, ρ₁ * [90%ile[Median(ln μ)] - 10%ile[Median(ln μ)]] reports the difference in average convergence rate for firms exposed to the value of the median markup in the respective percentiles. In specifications (3.4.6.7), this is for firms in sectors with 0% financial dependence. 90%ile[Median(ln μ)] * [ρ₁ + ρ₃ * Fin Dep_s(90%ile)] - 10%ile[Median(ln μ)] * [ρ₁ + ρ₃ * Fin Dep_s(90%ile)] reports the difference in average convergence rates, due to different median markups, for firms producing in sectors at the 90th percentile of financial dependence

Table 4: Speed of Convergence for Young Plants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$Median_{rst}[\ln \mu_{irst-1}] * 1(age \leq 5)$	0.0191** (0.00649)			0.0234** (0.00547)			0.0110 (0.0105)			0.0118 (0.00806)		
$Median_{rst}[\ln \mu_{irst-1}] * 1(age < 10)$		0.00937 (0.00542)			0.0130* (0.00511)			0.00775 (0.00858)			0.00316 (0.00735)	
$Median_{rst}[\ln \mu_{irst-1}] * [\ln(\frac{1}{age_{irst}})]$			0.00704* (0.00285)			0.00768** (0.00257)			0.00371 (0.00445)			0.00544 (0.00371)
$Median_{rst}[\ln \mu_{irst-1}] * 1(age \leq 5) * Fin Dep_s$							0.0396* (0.0200)			0.0346* (0.0173)		
$Median_{rst}[\ln \mu_{irst-1}] * 1(age < 10) * Fin Dep_s$								0.0197 (0.0170)			0.0189 (0.0153)	
$Median_{rst}[\ln \mu_{irst-1}] * [\ln(\frac{1}{age_{irst}})] * Fin Dep_s$									0.0187* (0.00811)			0.00775 (0.00707)
$1(age \leq 5)$	0.0631** (0.00333)			0.0343** (0.00322)			0.0628** (0.00358)			0.0297** (0.00346)		
$1(age < 10)$		0.0385** (0.00271)			-0.00423 (0.00316)			0.0395** (0.00292)			-0.00625 (0.00343)	
$\ln(\frac{1}{age_{irst}})$			0.0142** (0.00150)			0.0244** (0.00242)			0.0151** (0.00164)			0.0237** (0.00269)
$Median_{rst}[\ln(\mu_{irst-1})]$				0.00228 (0.00309)	0.00289 (0.00348)	0.0261** (0.00646)				0.00497 (0.00452)	0.00679 (0.00499)	0.0225* (0.00933)
$Median_{rst}[\ln(\mu_{irst-1})] * Fin Dep_s$										-0.00555 (0.00888)	-0.00422 (0.00926)	0.0138 (0.0182)
Influence of $Median_{rst-1}[\ln \mu_{irst-1}]$ on $g(k_{irst})$												
$\beta_2 * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$	0.036	0.0177	0.0133	0.0441	0.0245	0.0145	0.0207	0.0146	0.006	0.0223	0.00596	0.0103
$[\beta_2 + \beta_3 * Fin Dep_s(90\%ile)] * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$												
State-sector-year FE		Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No
Plant FE, Year FE		No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Observations	554871	554871	543752	554871	554871	543752	471868	471868	462020	471868	471868	462020

Standard errors in parentheses (* $p < 0.05$, ** $p < 0.01$). Standard errors are clustered at the state-sector level for specifications 1-3,7-9 and clustered at the plant-level for 4-6, 10-12. The inverse measure for competition, $Median_{rst}[\ln \mu_{irst-1}]$, is demeaned within sectors. $90\%ile[Median(\ln \mu)]$ and $10\%ile[Median(\ln \mu)]$ are the respective values for the 90th and the 10th percentile of $Median_{rst-1}[\ln \mu_{irst-1}]$ across state-sector-year observations. This way, $\beta_2 * [\ln \mu(90\%ile)] - \ln \mu(10\%ile)$ reports the difference in average capital growth for firms at the same young age level, but exposed to the different value of the median markup in the respective percentiles. In specifications (7-12), this is for firms in sectors with 0% financial dependence. Then, $\ln \mu(90\%ile) * [\beta_2 + \beta_3 * Fin Dep_s(90\%ile)] - \ln \mu(10\%ile) * [\beta_2 + \beta_3 * Fin Dep_s(90\%ile)]$ reports the difference in average capital growth, for firms at the same young age level and producing in sectors at the 90th percentile of financial dependence.

6 Competition policy reform: dereservation

In the previous section, I have analyzed the relationship between capital convergence and competition for the full sample of Indian manufacturing firms. In this setting, the motivation behind the identification was that the state-sector level of competition is plausibly exogenous to the individual firm. While this analysis benefits from the advantages of employing the full ASI sample, a potential limitation is that the underlying structural drivers of the variation in competition remain unexamined. To address this concern, I now exploit natural variation in competition arising from India's 1997 dereservation reform.

6.1 Description of dereservation reform

The dereservation reform consists of the staggered removal of the small scale industry (SSI) reservation policy. This reservation policy implied that only firms below a certain investment ceiling (Rs. 10 million at historical cost in 1999) were allowed to produce certain products. At the time of reservation, an exception was made for large industrial undertakings already producing the product. These firms were allowed to continue production, but with output capped at existing levels. In 1996, before the start of dereservation, around 1000 products were reserved for SSI. Starting in 1997, the Indian government starts with gradually removing the reservation policy. This process of dereservation peaks between 2002 and 2008. Importantly, the timing of dereservation is arguably exogenous. As an example, [Tewari and Wilde \(2014\)](#) document that there is considerable variation in the timing of dereservation within narrow product categories, such as vegetable oil. Such variation within products that broadly share demand and supply characteristics arguably limits the scope for a structural explanation of the timing of dereservation. Moreover, [Tewari and Wilde \(2014\)](#) also show that dereservation is uncorrelated with observable pre-policy characteristics of an industry. A more detailed description of dereservation is provided by [Tewari and Wilde \(2014\)](#) and [Martin et al. \(2014\)](#).

Dereservation has two distinct structural effects on incumbent firms. First, the direct effect of the removal of the investment ceiling is that incumbent firms are allowed to grow their capital stock. Second, there is the pro-competitive shock from dereservation on incumbents. The removal of the reservation policy implies that any firm can now produce the previously reserved product. As a result, there is scope for substantial entry into the production of dereserved products. In case the pro-competitive shock is the dominant effect on a subset of incumbents, I can utilize the dereservation reform as an exogenous increase in the degree of competition for this subset of plants.

6.2 Empirical analysis

6.2.1 Data

Data on the dereservation reform have been generously provided by Ishani Tewari, and a full description of this data is available in [Tewari and Wilde \(2014\)](#). Since I examine the pro-

competitive effect of dereservation on incumbent plants, I will restrict the sample to firms that are observed to be incumbent at least 2 years prior to dereservation. For the purpose of this exercise, I will define a plant as being dereserved if the main product that it produces has been dereserved during the financial year in which the plant is being observed. Since the implementation of dereservation starts in 1998, I use the NIC 1998 definition of sectors in the empirical analysis of dereservation.

6.2.2 Specifications

Event study In the previous subsection, I explained how dereservation can have two opposing effects on incumbents. The direct effect of the removal of the size-cap allows plants to grow their capital, whereas the pro-competitive effect reduces firm-revenue. In order for the dereservation reform to be a relevant for the analysis in this paper, i.e. as a shock to the competitive environment, it is helpful that for incumbent plants, the second, pro-competitive effect dominates the first, direct effect. To examine whether this is the case, I run the following event-study on the implementation of dereservation at time $t = 0$.

$$y_{irst} = \alpha_{rs} + \gamma_t + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \varepsilon_{irst} \quad (49)$$

where $y_{irst} = \mu_{irst}, g(k_{irst})$ and where I bin up the end-points and normalize $\beta_{-1} = 0$.

Capital convergence Following the event study, I analyze the effect of dereservation on plant-level rates of capital convergence. This analysis is structured analogously as in section 5. First, I examine if the dereservation reform slows down MRPK convergence. To this end, the analogue of specification (43) in the dereservation setting is:

$$\begin{aligned} MRPK_{irst} &= \alpha_{irs} + \beta_1 1(Dereserved_{irst-1}) + \rho_0 MRPK_{irst-1} \\ &+ \rho_1 MRPK_{irst-1} * 1(Dereserved_{irst-1}) + \beta_2 X_{irst} + \varepsilon_{irst} \end{aligned} \quad (50)$$

Here, $1(Dereserved_{irst-1})$ is an indicator variable for dereservation being implemented in period $t - 1$. In case dereservation leads to slower MRPK convergence due to the pro-competitive shock, then we would expect $\rho_1 > 0$.

The second specification updates equation (45), which focuses on capital growth for young firms, to the dereservation setting:

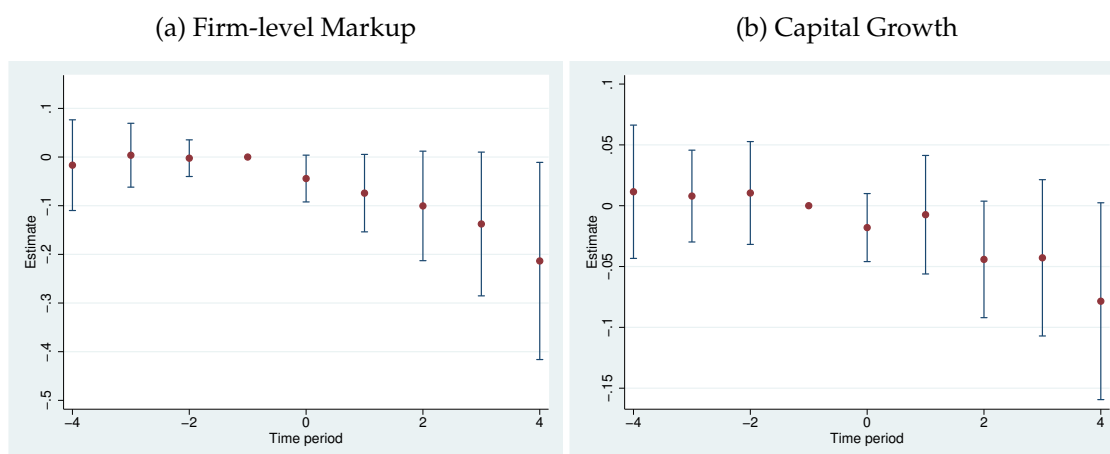
$$\begin{aligned} g(k_{irst}) &= \alpha_{irs} + \beta_1 (Dereserved_{irst-1}) + \beta_2 young_{irst} \\ &+ \beta_3 1(Dereserved_{irst-1}) * young_{irst} + \beta_4 X_{irst} + \varepsilon_{irst} \end{aligned} \quad (51)$$

where now the prediction is that $\beta_3 < 0$, in case the increase in competition due to dereservation leads to slower capital growth for young firms. The next subsection discusses the estimation results for the above specifications.

6.2.3 Results

Event Study: Pro-competitive shock First, I analyze to what extent dereservation has a pro-competitive impact on incumbent plants. Using specification (49), I examine the effect of dereservation on plant-level markups in Figure 2 in panel (a), and on plants' capital growth in panel (b).

Figure 2: Dereservation Event-study on Markups and Capital Growth



The figure displays the coefficients and 95% confidence intervals of an event-study regression on dereservation. Panel (a) displays the results of the regression $\mu_{irst} = \alpha_{irs} + \gamma_t + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \varepsilon_{irst}$, while panel (b) displays the results from the following regression: $g(k_{irst}) = \alpha_{rs} + \gamma_t + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \varepsilon_{irst}$. I impose the normalization that $\beta_{-1} = 0$.

Panel (a) indicates that firm-level markups fall after dereservation, which is consistent with the pro-competitive effect of dereservation being sufficiently salient. In addition, panel (b) displays that capital growth of incumbent firms tends to fall after dereservation. However, the estimated effects are only borderline statistically significant. A possible explanation for this finding is that the direct effect of dereservation, namely the removal of the investment ceiling, partly offsets the impact of the pro-competitive shock.

In appendix I.4, I further examine if there are cases where dereservation has a stronger pro-competitive effect than in the main event study. There, I find that for urban plants, which includes 62% of deserved incumbents, markups are generally lower. More importantly, I also find that dereservation leads to a more significant reduction in both markups and capital growth for urban plants compared to rural plants. Given these findings, it might be relevant to examine, in addition to the main estimation specifications, if dereservation has a stronger impact on capital growth for urban plants than for rural plants.³⁷

³⁷Note that aside from the birth year of the plant, which is central in the analysis of capital growth for young firms, geographic location is the only other unchangeable characteristics of a plant in the data. As such, the number of degrees of freedom in the analysis of heterogeneous treatment effects is inherently limited.

Capital convergence The main test of the model is presented in Table 5. For the baseline specifications, displayed in columns (1,2,4,5), the evidence is mixed. For the gross-revenue based measure, the estimated coefficients are small and insignificant. However, the effect of dereservation on MRPK convergence in column (4) is substantial and strongly significant. Next, specifications (3,6) indicate that dereservation especially slows down MRPK convergence for urban plants. This would be consistent with the findings from appendix I.4, which show that the pro-competitive impact of dereservation is particularly pronounced for urban incumbents. Therefore,

Table 6 demonstrates that dereservation has a negative impact on the capital growth for young firms. This finding is persistent across all measures for a firm being young. Therefore, the findings on both MRPK convergence and on capital growth for young firms are consistent with the prediction, along the lines of the model, that a pro-competitive shock slows down the rate of capital convergence.

Table 5: Speed of MRPK Convergence after Dereservation

	$MRPK_{irst}$ (Gross Revenue)			$MRPK_{irst}$ (Value added)		
	(1)	(2)	(3)	(4)	(5)	(6)
$1(Dereserved_{irst-1})$	0.0132 (0.0409)	-0.0396 (0.0467)	-0.0381 (0.0485)	0.127* (0.0611)	0.0679 (0.0628)	0.0607 (0.0651)
$1(Dereserved_{irst-1}) * 1(urban_{irs})$			0.0310 (0.0259)			0.0221 (0.0311)
$MRPK_{irst-1}(GR)$	0.806** (0.00873)	0.497** (0.0157)	0.519** (0.0160)			
$MRPK_{irst-1}(GR) * 1(Dereserved_{irst-1})$	0.00627 (0.0137)	-0.0130 (0.0151)	-0.0226 (0.0164)			
$MRPK_{irst-1}(GR) * 1(urban_{irs})$			-0.00173 (0.00642)			
$MRPK_{irst-1}(GR) * 1(Dereserved_{irst-1}) * 1(urban_{irs})$			0.0254* (0.0105)			
$MRPK_{irst-1}(VA)$				0.679** (0.0111)	0.347** (0.0142)	0.350** (0.0142)
$MRPK_{irst-1}(VA) * 1(Dereserved_{irst-1})$				0.0353* (0.0154)	0.0213 (0.0154)	0.00950 (0.0164)
$MRPK_{irst-1}(VA) * 1(urban_{irs})$						-0.00674 (0.00594)
$MRPK_{irst-1}(VA) * 1(Dereserved_{irst-1}) * 1(urban_{irs})$						0.0215* (0.00906)
State-sector FE	Yes	No	No	Yes	No	No
Plant FE	No	Yes	Yes	No	Yes	Yes
Observations	24858	25435	24294	23106	23617	23617

Standard errors in parentheses (* $p < 0.05$, ** $p < 0.01$).

All specifications include year fixed effects. Standard errors are clustered at the plant-level.

Sample includes all firms who were observed to be incumbent at least 2 years before dereservation.

Caveat To be clear, the evidence here should not be taken as arguing that dereservation is welfare reducing. This section is only providing evidence that dereservation has negative effects on capital convergence for incumbents, and thereby confirms the main prediction of the model. A discussion of the broader (welfare) effects of dereservation can be found in [García-](#)

Table 6: Speed of Convergence for Young Plants after Dereservation

	Plant-level Capital Growth $g(k_{irst}^i)$					
	(1)	(2)	(3)	(4)	(5)	(6)
$1(Dereserved_{irst})$	-0.00916 (0.0167)	0.0218* (0.00871)	-0.00620 (0.0176)	0.0269** (0.00853)	-0.101** (0.0261)	-0.0779** (0.0235)
$1(Dereserved_{irst}) * 1(age_{irst} \leq 5)$	-0.0705** (0.0209)	-0.121** (0.0212)				
$1(Dereserved_{irst}) * 1(age_{irst} < 10)$			-0.0429** (0.0123)	-0.0741** (0.0121)		
$1(Dereserved_{irst}) * [\ln(\frac{1}{age_{irst}})]$					-0.0316** (0.00881)	-0.0270** (0.00787)
$1(age_{irst} \leq 5)$	0.0683** (0.0158)	0.0576** (0.0121)				
$1(age_{irst} < 10)$			0.0389** (0.0117)	0.0365** (0.00834)		
$\ln(\frac{1}{age_{irst}})$					0.0204* (0.00788)	0.0277** (0.00625)
State-sector-year FE	Yes	No	Yes	No	Yes	No
Firm FE, year FE	No	Yes	No	Yes	No	Yes
Observations	43548	43548	43548	43548	43210	43210

Standard errors, clustered at the sector level, in parentheses (* $p < 0.05$, ** $p < 0.01$).

Sample includes all firms who were observed to be an incumbent in the reserved sector more than 2 years before dereservation.

Santana and Pijoan-Mas (2014); Martin et al. (2014); Tewari and Wilde (2014).

7 Conclusion

This paper examines the relation between capital misallocation and the degree of competition. The theory describes how competition affects steady-state misallocation in a setting with firm-level productivity volatility and financial constraints. Competition plays a dual role in affecting misallocation. On the one hand, both markup levels and markup dispersion tend to fall with competition, which unambiguously improves allocative efficiency in a setting without financial constraints. On the other hand, in a setting with financial constraints, a reduction in markups slows down capital accumulation, as the rate of self-financed investment shrinks. Thus, the positive impact of competition on steady-state misallocation is reduced by the presence of financial frictions. While the beneficial impact of competition is known in the literature, the negative impact of competition in a setting with financial constraints was previously under examined in the literature.

Empirically, the prediction that the firm-level speed of capital convergence falls with competition is confirmed for the full sample of Indian manufacturing firms. This effect is particularly pronounced in sectors with higher levels of financial dependence, as predicted by the theory. I also exploit natural variation in the level of competition, arising from India's 1997 dereservation reform, and again confirm the qualitative predictions of the model.

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A Labor market equilibrium

A.1 Expressions for output and TFP

We can express each firm's capital as a share of aggregate capital. To that end, we rewrite capital demand for constrained and unconstrained firms as:

$$k_{it} = \mu_{it}^{\frac{1}{\eta-1}} a_{it}^{\frac{\eta}{1-\eta}} \frac{Q_t}{M} \left(\frac{P_t(1-\alpha)}{w_t} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \left(\frac{\alpha}{\omega_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}}$$

where $\omega_{it} = r_{it}$ if the firm is unconstrained, and $\omega_{it} > r_{it}$ otherwise. Writing k_{it} as a fraction of aggregate capital, we find:

$$k_{it} = \frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} K_t$$

Similarly, for labor, starting from the labor demand equation $l_{it} = \left(\frac{(1-\alpha)P_t}{\mu_{it}w_t} \left(\frac{Q_t}{M} \right)^{1-\eta} a_{it}^{\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$

$$l_{it} = \frac{\left(\frac{a_{it}^{\eta} k_{it}^{\alpha\eta}}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^{\eta} k_{it}^{\alpha\eta}}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}}} L$$

Plugging in the value for k_{it}

$$l_{it} = \frac{\frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}}{\sum_{i=1}^M \frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}} L$$

The expressions for k_{it}, l_{it} can then be used to find an expression for the composite good:

$$Q_t = M^{1-\frac{1}{\eta}} \left[\sum_{i=1}^M (y_{it})^{\eta} \right]^{\frac{1}{\eta}} = M^{1-\frac{1}{\eta}} \left[\sum_{i=1}^M (a_{it} k_{it}^{\alpha\eta} l_{it}^{1-\alpha})^{\eta} \right]^{\frac{1}{\eta}}.$$

$$Q_t = MK_t^{\alpha} L^{1-\alpha} \left[E_{it} \left(a_{it}^{\eta} \left(\frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \left(\frac{\frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}}{\sum_{i=1}^M \frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^M \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}} \right)^{\eta-\alpha\eta} \right]^{\frac{1}{\eta}}$$

Therefore:

$$Q_t = TFP_t K_t^\alpha L^{1-\alpha} \quad (52)$$

where

$$TFP_t \equiv M \left[E_{it} \left(a_{it}^\eta \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}} \right)^{\eta-\alpha\eta} \right)^{\frac{1}{\eta}} \right] \quad (53)$$

A.2 Labor market equilibrium

$$L = \sum_{i=1}^M \left(\frac{(1-\alpha) P_t}{\mu_{it}} \frac{P_t}{w_t} \left(\frac{Q_t}{M} \right)^{1-\eta} a_{it}^\eta k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

$$L = \left((1-\alpha) \frac{P_t}{w_t} \left(\frac{Q_t}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

$$L = \left((1-\alpha) \frac{P_t}{w_t} \left(\frac{TFP_t K_t^\alpha L^{1-\alpha}}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} K_t^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

$$L^{\frac{\alpha}{1+\alpha\eta-\eta}} = \left((1-\alpha) \frac{P_t}{w_t} \left(\frac{TFP_t}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} K_t^{\frac{\alpha}{1+\alpha\eta-\eta}} \sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

$$\frac{P_t}{w_t} = \left(\frac{L}{K_t} \right)^\alpha \frac{1}{(1-\alpha) \left(\frac{TFP_t}{M} \right)^{1-\eta}} \left[\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right]^{\eta-\alpha\eta-1}$$

So $\frac{P_t}{w_t}$ is decreasing in TFP and in $\left[\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it}} \left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^M \left(\frac{a_{it}^\eta}{\mu_{it} \omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right]$.

B Markup dispersion and competition

The goal in this appendix section is to show that for any $t - s$:

$$\frac{\partial \frac{\mu_L}{\mu_\tau}}{\partial M} \geq 0 \quad (54)$$

Equation (9) implies that $\mu_{it} = \frac{1-\eta \frac{y_{it}^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_{it}^\eta}{\sum_i y_{it}^\eta}\right)}$, which implies:

$$\frac{\mu_L}{\mu_\tau} = \frac{\frac{1-\eta \frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_L^\eta}{\sum_i y_{it}^\eta}\right)}}{\frac{1-\eta \frac{y_{t-s}^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_{t-s}^\eta}{\sum_i y_{it}^\eta}\right)}} \quad (55)$$

At the same time, the following relation holds, following the derivation in appendix A.1

$$\frac{y_{G_\tau}}{y_L} = \left(\frac{a_H}{a_L}\right)^{\eta + \left(\frac{\eta}{1-\eta}\right)\left(\frac{1-\eta}{1+\alpha\eta-\eta}\right)} \left(\frac{\mu_L}{\mu_\tau}\right)^{\frac{1}{1+\alpha\eta-\eta}} G_\tau^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \quad (56)$$

Equations 57, 58 will together determine that conditional on G_τ , (54) holds. Here is the outline of the proof:

- Step 1: Suppose $\frac{\partial \frac{y_{G_\tau}}{y_L}}{\partial M} = 0$, then equation 57 implies that $\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} < 0$. This contradicts 58 since $\frac{\partial \frac{y_L}{\mu_\tau}}{\partial M} < 0$.
- Step 2: $\frac{\partial \frac{y_{G_\tau}}{y_L}}{\partial M} < 0$ also leads to a contradiction with 58, hence $\frac{\partial \frac{y_{G_\tau}}{y_L}}{\partial M} > 0$ is true.
- Step 3: $\frac{\partial \frac{y_{G_\tau}}{y_L}}{\partial M} > 0$ implies $\frac{\partial \frac{\mu_L}{\mu_\tau}}{\partial M} \geq 0$

Step 1:

1. Suppose that $\frac{y_{G_\tau}}{y_L}$ is constant: $\frac{y_{G_\tau}}{y_L} \equiv \xi_{G_\tau}^{1/\eta}$.
2. Define $\zeta \equiv [Prob(a_i = a_L) + \sum_t Prob(a_{it} = a_H \& s = t - \tau) \xi_{G_\tau}]$. Then, note that $\frac{y_{G_\tau}}{\sum_M y_i^\eta} = \frac{\xi_{G_\tau}}{M\zeta}$ and $\frac{y_L^\eta}{\sum_M y_i^\eta} = \frac{1}{M\zeta}$.³⁸
3. This then entails the following ratio of markups: $\frac{\mu_\tau}{\mu_L} = \frac{1 - \frac{\eta \xi_{G_\tau}}{M\zeta}}{1 - \frac{\xi_{G_\tau}}{M\zeta}} \frac{1 - \frac{1}{M\zeta}}{1 - \frac{\eta}{M\zeta}} = \frac{M\zeta - 1 - \eta \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M\zeta}}{M\zeta - \eta - \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M\zeta}}$
4. which implies that

$$\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} = \frac{\left(\zeta - \frac{\eta \xi_{G_\tau}}{M^2 \zeta}\right) \left(M\zeta - \eta - \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M\zeta}\right) - \left(M\zeta - 1 - \eta \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M\zeta}\right) \left(\zeta - \frac{\eta \xi_{G_\tau}}{M^2 \zeta}\right)}{\left(M\zeta - \eta - \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M\zeta}\right)^2}$$

³⁸To see this, note that $\sum_M y_i^\eta = M[Prob(a_i = a_L) y_L^\eta + \sum_t Prob(a_{it} = a_H \& s = t - \tau) \xi_{G_\tau} y_L^\eta] = \zeta M y_L^\eta$.

5. Therefore³⁹

$$\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} = \frac{\left(\zeta - \frac{\eta \xi_{G_\tau}}{M^2 \zeta}\right) (-\eta - \xi_{G_\tau} + 1 + \eta \xi_{G_\tau})}{\left(M \zeta - \eta - \xi_{G_\tau} + \frac{\eta \xi_{G_\tau}}{M \zeta}\right)^2} < 0$$

Step 2 : It is then straightforward to check that supposing $\frac{\partial \frac{y_{t-s}}{y_L}}{\partial M} < 0$, would also imply that $\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} < 0$, again contradicting equation 58.

Step 3 :

- Because of the result in Step 1 and Step 2, it has to be the case that $\frac{\partial \frac{y_{t-s}}{y_L}}{\partial M} > 0$, while at the same time $\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} < 0$. This is consistent with equation 58.
- Moreover, the global, strict inequality in $\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} < 0$, under constant output shares, implies that it is possible to marginally increase y_{t-s}/y_L as M increases, and at the same time allow for marginally lower $\frac{\mu_\tau}{\mu_L}$.
- Since the above logic (step 1, step 2, and the previous 2 bullet points) hold globally, $\frac{\partial \frac{\mu_\tau}{\mu_L}}{\partial M} < 0$ holds globally as well.

³⁹The reason this is always negative, is that all terms in brackets are positive except $-\eta - \xi_{G_\tau} + 1 + \eta \xi_{G_\tau} < 0$. The reason $\left(\zeta - \frac{\eta \xi_{G_\tau}}{M^2 \zeta}\right)$ is positive is that this term is decreasing in the share of high productivity firms, but it is increasing faster in the number of firms. Moreover, the term is positive for $M = 1, 2$. Since the share of high productivity firms can only be decreased by increasing the number of firms, this implies that the term is always positive. Second, $-\eta - \xi_{G_\tau} + 1 + \eta \xi_{G_\tau} < 0$ since $1 - \eta < (1 - \eta) \xi_{G_\tau} \implies 1 + \eta \xi_{G_\tau} < \eta + \xi_{G_\tau}$. Finally the denominator is positive since it is squared.

C Comparative statics on capital growth rate

C.1 Impact of firm-level markup

In this section I show that:

$$\frac{\partial \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right)}{\partial M} < 0$$

As a first step, note that the firm level markup can be written as proportional to $\eta: 1/\mu_{it} = \xi\eta$. This is because the lower bound on μ_{it} is $1/\eta$, and this markup can only increase with $1/M$ (see Appendix D, where I show that the markup of all firm types increase with $1/M$). Therefore, I can rewrite the term under consideration as:

$$\left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) = \left([\xi(M)\eta(1-\alpha)]^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - [\xi(M)\eta(1-\alpha)]^{\frac{1}{1+\alpha\eta-\eta}} \right) \equiv B_{it}$$

with $0 < \xi(M) \leq 1$, $\frac{\partial \xi(M)}{\partial M} > 0$.

We can then show that the term under consideration falls with M .⁴⁰

$$\frac{\partial B_{it}}{\partial M} = \frac{(\eta - \alpha\eta)^{\frac{1}{1+\alpha\eta-\eta}}}{1 + \alpha\eta - \eta} \frac{\partial \xi(M)}{\partial M} \left(\xi(M)^{\frac{2(\eta-\alpha\eta)-1}{1+\alpha\eta-\eta}} - \xi(M)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} \right) < 0$$

In this equation, all terms are positive except the term within brackets, which renders the full equation negative. To see this, note that $\eta - \alpha\eta > 2(\eta - \alpha\eta) - 1$ and that $\frac{\partial \xi(M)^\zeta}{\partial \zeta} = \xi(M)^\zeta \ln \xi$. Since $\ln \xi \leq 0$ and $\frac{\partial \xi(M)}{\partial M} > 0$, $\frac{\partial B_{it}}{\partial M} < 0$.

C.2 Analyzing the factor price ratio

Comparative statics on TFP Here, there are two cases: either $\frac{\partial TFP_t}{\partial M} < 0$, or $\frac{\partial TFP_t}{\partial M} \geq 0$. In case $\frac{\partial TFP_t}{\partial M} < 0$, then Proposition 2.3 is proven. In case $\frac{\partial TFP_t}{\partial M} \geq 0$, then this is consistent with $\frac{\partial P_t/w_t}{\partial M} < 0$, depending on the other components of F_L .

Comparative statics on Ω Next, if the Ω term falls, then the current proposition is proven.

Comparative statics on capital Then, I analyze the comparative statics on K , described in equation (33)

$$K^{1-\alpha} = TFP L^{1-\alpha} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \alpha^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{a_L^\eta}{\mu_L r_L^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \left[Prob(a_{it} = a_L) + \sum_{\tau=1}^{\infty} Prob(a_{it} = a_H \& s = t - \tau) G_\tau \right]$$

⁴⁰The intermediate step is:

$$\frac{\partial B_{it}}{\partial M} = (\eta - \alpha\eta)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} \frac{\eta - \alpha\eta}{1 + \alpha\eta - \eta} \xi(M)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}-1} \frac{\partial \xi(M)}{\partial M} - (\eta - \alpha\eta)^{\frac{1}{1+\alpha\eta-\eta}} \frac{1}{1 + \alpha\eta - \eta} \xi(M)^{\frac{1}{1+\alpha\eta-\eta}-1} \frac{\partial \xi(M)}{\partial M}$$

Remembering that $\frac{\partial P/w}{\partial K} < 0$, we notice that $\frac{\partial K}{\partial \underline{P}}, \frac{\partial K}{\partial TFP}, \frac{\partial K}{\partial G_\tau} > 0$, and that $\frac{\partial K}{\partial \mu_L} < 0$. Moreover, the maximum level of G_τ is decreasing in μ_H , hence $\frac{\partial K}{\partial \mu_H} < 0$. I now examine each of these components.

- First, the analysis of the comparative statics on TFP is analogous to the previous paragraph. There are two cases: either $\frac{\partial TFP}{\partial M} < 0$, or $\frac{\partial TFP}{\partial M} \geq 0$. In case $\frac{\partial TFP}{\partial M} < 0$, then Proposition 2.3 is proven. In case $\frac{\partial TFP}{\partial M} \geq 0$, then this is consistent with $\frac{\partial P/w}{\partial M} < 0$, depending on the other components of (60), (33).
- Second, appendix D demonstrates that $\frac{\partial \mu_L}{\partial M} < 0, \frac{\partial \mu_H}{\partial M} < 0$. Hence, declining markups put upward pressure on K_t as M increases.
- Next, r_L, r_H are constant, where r_H being constant is a consequence of the model, and r_L being constant is an assumption.
- Then, for G there are two cases. First, in case $\frac{\partial G}{\partial M} < 0$, Proposition 2.3 is proven. The other case is that $\frac{\partial G}{\partial M} \geq 0$. However, since P/w is endogenous, there needs to be a driving factor for $\frac{\partial P/w}{\partial M} \geq 0$. None of the possible factors, examined above, could lead to this without confirming the proposition. The final factor, examined in the next point, can also not be that driving factor without confirming the proposition.
- Finally, for P/w there are two cases. In case $\frac{\partial P/w}{\partial M} < 0$, this part of the proof is concluded. The other case is that $\frac{\partial P/w}{\partial M} \geq 0$. However, since P/w is endogenous, there needs to be a driving factor for $\frac{\partial P/w}{\partial M} \geq 0$. None of the possible factors, examined above, could lead to this without confirming the proposition.

D Markup levels

In this section, I will demonstrate that the following statement is true:

- $\frac{\partial \mu_H}{\partial M} < 0, \frac{\partial \mu_L}{\partial M} < 0$

The proof centers around equations (23), (24) that implicitly characterize the distribution of markups:

$$\mu_L(a_L, k_L^*, F(a, k), M) \equiv \frac{1 - M^{\eta-1} \eta \frac{(a_L(k_L^*))^\alpha (l_L^*)^{1-\alpha} \eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(a_L(k_L^*))^\alpha (l_L^*)^{1-\alpha} \eta}{Q^\eta} \right)}$$

$$\mu_H(a_H, k_H^*, F(a, k), M) \equiv \frac{1 - M^{\eta-1} \eta \frac{(a_H(k_H^*))^\alpha (l_H^*)^{1-\alpha} \eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(a_H(k_H^*))^\alpha (l_H^*)^{1-\alpha} \eta}{Q^\eta} \right)}$$

Comparative statics on M

- I will now first demonstrate that $\frac{\partial \mu_L}{\partial M} < 0$. To that end, suppose the opposite, that $\frac{\partial \mu_L}{\partial M} \geq 0$.

This requires $\frac{\partial \left(\frac{y_L^\eta}{\sum_{i=1}^M y_{it}^\eta} \right)}{\partial M} \geq 0$, since ε_L falls with $\frac{y_L^\eta}{\sum_{i=1}^M y_{it}^\eta}$.

In turn, $\frac{\partial \left(\frac{y_L^\eta}{\sum_{i=1}^M y_{it}^\eta} \right)}{\partial M} \geq 0$ requires that for some $t-s > 0$: $\frac{\partial \left(\frac{y_{t-s}}{y_L} \right)}{\partial M} \leq 0$. However, appendix section B has demonstrated that $\forall t-s > 0$: $\frac{\partial \left(\frac{y_{t-s}}{y_L} \right)}{\partial M} > 0$, which entails a contradiction.

- Now, I show that $\frac{\partial \mu_H}{\partial M} < 0$. Appendix section B, shows that $\frac{\partial \left(\frac{\mu_H}{\partial M} \right)}{\partial M} < 0$, and I know from above that $\frac{\partial \mu_L}{\partial M} < 0$. Together this implies that $\frac{\partial \mu_H}{\partial M} < 0$. QED.

Further notes:

$$\mu_\tau(a_H, G_\tau k_L^*, F(a, k), M) \equiv \frac{1 - M^{\eta-1} \eta \frac{(y(a_H, G_\tau k_L^*), F(a, k))^\eta}{Q^\eta}}{\eta \left(1 - M^{\eta-1} \frac{(y(a_H, G_\tau k_L^*), F(a, k))^\eta}{Q^\eta} \right)}$$

- Note that for any $t-s > 0$: $\mu_L < \mu_\tau \leq \mu_H$, since $y_L < y(a_H, G_\tau k_L^*), F(a, k) \leq y_H$, and ε_{it} falls with $\frac{y_{it}^\eta}{\sum_{i=1}^M y_{it}^\eta}$.
- At the same time: $\mu_{t+1-s} \geq \mu_\tau$ because $G_{t+1-s} \geq G_\tau$, and therefore $y(a_H, G_{t+1-s} k_L^*) \geq y(a_H, G_\tau k_L^*)$.

E Finalizing the proposition

E.1 Outline of proof

The theory so far has demonstrated that:⁴¹

Lemma E.1. • For any $\tau > 0$:

$$\frac{\partial \omega_\tau}{\partial M} \geq 0$$

⁴¹This proof is preliminary and will be updated in the next few weeks.

and $(\Phi_\tau > 0) \implies \frac{\partial \omega_\tau}{\partial M} > 0$

• or

$$\frac{\partial TFP}{\partial M} < 0$$

• or

$$\frac{\partial \Omega}{\partial M} < 0$$

To show this, refer back to Lemma 2.2. Since r_L, r_H are constant⁴², the question is how ω_τ behaves for firms with $\Phi_\tau > 0$. For these firms, equation (27) directly implies that a sufficient condition for the proposition to be true is that for any τ where $\Phi_\tau > 0$, $\frac{\partial G_\tau}{\partial M} < 0$ and $\frac{\partial \mu_\tau}{\partial M} \leq 0$. In the proof, I am able to show that this condition holds, or if it does not hold, then $\frac{\partial TFP}{\partial M} < 0$ or $\frac{\partial \Omega}{\partial M} < 0$.

E.1.1 Markup dispersion

As a first step in demonstrating the proposition, I show in appendix B that

$$\frac{\partial \mu_L}{\partial M} \leq 0$$

Since μ_L is the lowest markup within a given steady state, and since $\frac{1}{\eta}$ is the lowest possible markup, this result implies that markup dispersion falls with M . This is intuitive, since as $M \rightarrow \infty$, markups of all firms tend to $\frac{1}{\eta}$.

To show this, I focus on the relation between the markup ratio:

$$\frac{\mu_L}{\mu_\tau} = \frac{1 - \eta \frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_L^\eta}{\sum_i y_{it}^\eta} \right)} \quad (57)$$

$$\frac{\mu_L}{\mu_\tau} = \frac{1 - \eta \frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_\tau^\eta}{\sum_i y_{it}^\eta} \right)}$$

and the output ratio:

$$\frac{y_{G_\tau}}{y_L} = \left(\frac{a_H}{a_L} \right)^{\eta + \left(\frac{\eta}{1-\eta} \right) \left(\frac{1-\eta}{1+\alpha\eta-\eta} \right)} \left(\frac{\mu_L}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}} G_\tau^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \quad (58)$$

Equations 57, 58 will together determine that conditional on G_τ , $\frac{\partial \mu_L}{\partial M} > 0$. Intuitively, the nonlinearity of $\frac{\mu_L}{\mu_\tau}$ in $\frac{y_L^\eta}{\sum_i y_{it}^\eta}, \frac{y_{G_\tau}^\eta}{\sum_i y_{it}^\eta}$ as function of M in equation 57 puts upward pressure on $\frac{\mu_L}{\mu_\tau}$, even if $\frac{y_{G_\tau}}{y_L}$ would remain constant. This upward pressure then leads to $\frac{\mu_L}{\mu_\tau}$ increasing with M , while $\frac{y_L}{y_{G_\tau}}$ is falling with M .

E.1.2 Comparative statics on the growth rate of capital

After demonstrating that $\frac{\partial \mu_L}{\partial M} \leq 0$, I will now show that

$$\forall t - s : \frac{\partial G_\tau}{\partial M} \leq 0, \text{ or } \frac{\partial TFP}{\partial M} < 0, \text{ or } \frac{\partial \Omega}{\partial M} < 0$$

⁴²Specifically, r_H being constant is an implication of the model, while r_L is assumed constant. Relaxing this assumption is work in progress.

A sufficient condition to show that $\frac{\partial G_\tau}{\partial M} \leq 0$ is that for any t : $g\left(\mu_{it}, \frac{P_t}{w_t} | G_{it,s}\right)$ since $G_{it,s} = G_{it-1,s}(1 + g(k_{it}))$ and $G_{it-1,s} = \Pi_{\tau=s}^{t-1}(1 + g(k_{i\tau}))$. Combining equations 71 and 22, note that:⁴³

$$g(k_{it+1}) = \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \frac{P_t}{w_t} \frac{r_L}{\alpha} \left(G_{it,s}^{\eta-1} \left(\frac{a_H}{a_L} \right)^\eta (1-\alpha)^{\alpha\eta-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} - \delta \quad (59)$$

and therefore:

$$\begin{aligned} \frac{\partial g\left(\mu_\tau, \frac{P}{w} | G_\tau\right)}{\partial M} &= \frac{r_L}{\alpha} \left(G_\tau^{\eta-1} \left(\frac{a_H}{a_L} \right)^\eta (1-\alpha)^{\alpha\eta-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \left[\frac{\partial \left(\left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right)}{\partial M} \right] \frac{P}{w} \\ &\quad + \left(\left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \frac{\partial(P/w)}{\partial M} \end{aligned} \quad (60)$$

Now, I will first discuss why $\frac{\partial \left(\left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right)}{\partial M} < 0$, and subsequently demonstrate that $\left(\frac{\partial P/w}{\partial M} < 0 \text{ or } \frac{dTFP}{dM} < 0, \text{ or } \frac{\partial \Omega}{\partial M} < 0 \right)$.

Impact of firm-level markup In appendix section C.1, I demonstrate that

$$\frac{\partial \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right)}{\partial M} < 0$$

The intuition behind this result is that the term within brackets is increasing in μ_τ , and μ_τ falls with M .

Impact of the relative factor price The final task is to demonstrate that

$$\left(\frac{\partial P/w}{\partial M} < 0 \text{ or } \frac{dTFP}{dM} < 0, \text{ or } \frac{\partial \Omega}{\partial M} < 0 \right) \quad (61)$$

In appendix section C.2, I analyze the following relationship 31 from the labor market equilibrium to show that 61 holds.

$$\frac{P}{w} = F_L(L, K, TFP, M, \Omega)$$

The intuition is that as M increases, labor demand intensifies, leading to a lower $\frac{P}{w}$, unless TFP or Ω fall.

⁴³This can be seen from this equation:

$$\begin{aligned} g(k_{it+1}) &= \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \left(\frac{P_t}{w_t} \left(\frac{Q_t}{M} \right)^{1-\eta} a_{it}^\eta \right)^{\frac{1}{1+\alpha\eta-\eta}} \\ &\quad \left(G_t \mu_L^{\frac{1}{\eta-1}} a_L^{\frac{\eta}{1-\eta}} \frac{Q_t}{M} \left(\frac{P_t(1-\alpha)}{w_t} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \left(\frac{\alpha}{r_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \right)^{\frac{\eta-1}{1+\alpha\eta-\eta}} - \delta \end{aligned}$$

Note that all low-productivity unconstrained firms have the same r_L , since capital is the only savings device.

E.2 Tightening the Lemma

Now return back to the lemma, the first bullet point holds if $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$ and if for $\tau > 0$: $\Phi_\tau > 0$, then $\frac{\partial G_\tau}{\partial M} < 0$.

The current proof will show that the following statement is always true: $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$. Given the above proposition, if I can demonstrate that

$$\left[\left(\frac{\partial \Omega}{\partial M} < 0 \text{ or } \frac{\partial TFP}{\partial M} < 0 \right) \text{ and not } \forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0 \right]$$

results in a contradiction, then I have demonstrated that $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$. What then remains to be shown is that the strict inequality applies in the relevant cases, such that the first bullet point of the lemma is proven to always hold.

- From appendix I know: $\frac{\partial \mu_H}{\partial M} < 0$, $\frac{\partial \mu_L}{\partial M} < 0$. Therefore, the current theory is only uncertain about the sign of $\frac{\partial \mu_\tau}{\partial M}$ for any of the τ . Hence, there are two theoretically possible cases for the signs of $\frac{\partial \mu_\tau}{\partial M}$:
 - Markup-Case 1: $\forall \tau : \frac{\partial \mu_\tau}{\partial M} \leq 0$.
 - Markup-Case 2: there exists a τ such that $\frac{\partial \mu_\tau}{\partial M} > 0$
- At the same time, the proposition can be split up in two non-exclusive cases:
 - Lemma-Case 1: The statement "For any $\tau > 0$: $\frac{\partial \omega_\tau}{\partial M} \geq 0$ and if for $\tau > 0$: $\Phi_\tau > 0$, then $\frac{\partial \omega_\tau}{\partial M} > 0$ " holds. In that case I am done.
 - Lemma-Case 2: $(\frac{\partial \Omega}{\partial M} < 0 \text{ or } \frac{\partial TFP}{\partial M} < 0)$. The question is if Case 2 can be true without Case 1 being true. To examine this, I will analyze the following two possible scenarios:
 - * Scenario 1: Lemma-Case 2 holds and Markup-Case 1 holds.
 - * Scenario 2: Lemma-Case 2 holds and Markup-Case 2 holds.

I will show that in Scenario 1, Lemma-Case 1 necessarily holds as well. Second, I show that Scenario 2 is a contradiction. Therefore, Lemma-Case 1 always holds and the proof is completed.

E.3 Scenario 1

In Scenario 1, I suppose that Lemma-Case 2 and Markup-case 1 hold, i.e. that $(\frac{\partial \Omega}{\partial M} < 0 \text{ or } \frac{\partial TFP}{\partial M} < 0)$ holds and that $\forall \tau : \frac{\partial \mu_\tau}{\partial M} \leq 0$. In this case, I will show that it is necessarily the case that $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$. Once I have shown this, I am done for this scenario.

In other words, the idea is that in the scenario where the following holds: $\frac{\partial \mu_H}{\partial M} < 0$, $\frac{\partial \mu_L}{\partial M} < 0$ and $\forall \tau : \frac{\partial \mu_\tau}{\partial M} \leq 0$, with $\frac{\partial^{\mu_\tau | G_\tau} \mu_L}{\partial M} < 0$, i.e. all markups fall and markup dispersion falls, then the only way $(\frac{\partial \Omega}{\partial M} < 0 \text{ or } \frac{\partial TFP}{\partial M} < 0)$ is possible, is if $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$.

Proof for this scenario

- Suppose $(\frac{\partial \Omega}{\partial M} < 0 \text{ or } \frac{\partial TFP}{\partial M} < 0)$ holds and that $\forall \tau : \frac{\partial \mu_\tau}{\partial M} \leq 0$
- Note that the capital growth rate is linked across τ . Either it is weakly higher for all τ , or it is weakly lower for all τ . This is evident from the expression for G_τ , and the expression for g_τ .
- Given the previous point, there are then two cases within this Scenario 1:

- Case 1.1 $\forall \tau : \frac{\partial G_\tau}{\partial M} \leq 0$. If this case holds, then I am done for this scenario.
- Case 1.2. $(\Phi_\tau > 0) \implies \frac{\partial G_\tau}{\partial M} > 0$. This case will result in a contradiction. Therefore, within Scenario 1, only case 1.1. is a possible scenario.
- Suppose Case 1.2. holds. In that case, from the expression for the capital growth rate (in section 2.6.3), it needs to be the case that $\frac{P}{w}$ increases (since the only other variable affected by M - μ_τ - is supposed to be decreasing.) However, consider the expression for $\frac{P}{w}$:

$$\left(\frac{w}{P}\right)^{\frac{1}{1+\alpha\eta-\eta}} = \frac{1}{L} \left((1-\alpha) \left(\frac{Q}{M}\right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} k_L^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \left[\sum_{i:a_i=a_L} \left(\frac{a_L^\eta}{\mu_L}\right)^{\frac{1}{1+\alpha\eta-\eta}} + \sum_{s:s=\tau} \sum_{i:a_i=a_H \& s=\tau} \left(\frac{a_H^\eta}{\mu_\tau} G_\tau^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}} \right]$$

All the components on the RHS of this equation are weakly increasing with M in this case 1.2.:

- The term within square brackets weakly increases, since $\forall \tau : \frac{\partial \mu_\tau}{\partial M} \leq 0$ and $\forall \tau : \frac{\partial G_\tau}{\partial M} \geq 0$.
- $\frac{Q}{M}$ increases. The reason is that: all markups decrease, so that increases capital accumulation. Moreover, G_τ weakly increases. Hence, the firms with a_H hire more workers. Since these firms have a higher physical marginal product than the firms with a_L , the allocative efficiency is improved.
- Since $\frac{P}{w}$ decreases, Case 1.2. results in a contradiction and Case 1.1. is the only possible case in Scenario 1.

E.4 Scenario 2

Scenario 2 supposes that $(\frac{\partial \Omega}{\partial M} < 0$ or $\frac{\partial TFP}{\partial M} < 0)$ holds and for some $\tau : \frac{\partial \mu_\tau}{\partial M} \geq 0$. I want to show that this requires $\forall \tau : \frac{\partial G_\tau}{\partial M} \geq 0$, and that this implies a contradiction.

To prove the above statement:

- Step 1: note that there is downward pressure on μ_τ from the increase in M. The only way μ_τ can increase, is if G_τ is sufficiently high. This is a direct corollary from the theoretical findings in appendix section B.
- Since the capital growth rates of all the τ are linked, this then implies that $\frac{\partial G_\tau}{\partial M} \geq 0$ for all τ where $\Phi_\tau > 0$
- Step 2: $\frac{\partial G_\tau}{\partial M} \geq 0$ for all τ where $\Phi_\tau > 0$, allocative efficiency improves:
 - For constrained firms, the gap between k_H^* and k_τ decreases.
 - Hence, on aggregate more labor is employed in firms with higher levels of capital and higher productivity. As such, aggregate output and allocative efficiency are increasing.
 - If we consider again the following expression:

$$\left(\frac{w}{P}\right)^{\frac{1}{1+\alpha\eta-\eta}} = \frac{1}{L} \left((1-\alpha) \left(\frac{Q}{M}\right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} k_L^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}$$

$$\left[\sum_{i:a_i=a_L} \left(\frac{a_L^\eta}{\mu_L}\right)^{\frac{1}{1+\alpha\eta-\eta}} + \sum_{s:s=\tau} \sum_{i:a_i=a_H \& s=\tau} \left(\frac{a_H^\eta}{\mu_\tau} G_\tau^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}} \right]$$

Then I am showing that the aggregate variables are increasing. The remaining term to worry about is $\sum_{i:a_i=a_H \& s=\tau} \frac{a_H^\eta}{\mu_\tau} G_\tau^{\alpha\eta}$, where μ_{tau} and G_τ are moving in opposite directions. However, the individual labor demand of any firm with higher μ_{tau} has to be higher when μ_{tau} increases. Otherwise, this would violate the relationship between markups and labor shares, where markups are monotonically increasing in the labor share of the firm.

- Hence, aggregate labor demand unambiguously increases, and therefore $\frac{w}{P}$ has to increase.
- Therefore, this scenario entails a contradiction, since the only way μ_τ, G_τ could be increasing with M , is if $\frac{w}{P}$ is falling with M . Since we now see that Scenario 2 entails the opposite, this scenario entails a contradiction.

F Symmetric equilibrium

For completeness, and to provide intuition, here we provide the characteristics of a symmetric equilibrium:

- First, we know that the optimal firm-level markup is $\mu_{it} = \frac{1-\eta \frac{y_{it}^\eta}{\sum_i y_{it}^\eta}}{\eta \left(1 - \frac{y_{it}^\eta}{\sum_i y_{it}^\eta}\right)}$. This implies that in a symmetric equilibrium, we have $\mu_{it} = \frac{1-\frac{\eta}{M}}{\eta(1-\frac{1}{M})} = \frac{M-\eta}{\eta(M-1)}$.
- All firms have the same capital level, hence $k_{it} = \frac{K_t}{M}$.
- Output $y_{it} = \frac{K_t^\alpha L^{1-\alpha}}{M}$. Therefore $Q = M^{1-\frac{1}{\eta}} \left[\sum_{i=1}^M \left(\frac{K_t^\alpha L^{1-\alpha}}{M} \right)^\eta \right]^{\frac{1}{\eta}} = K^\alpha L^{1-\alpha}$.

Now, what remains is to solve for the relative prices P_t/w_t , which we solve for in the labor market equilibrium.

F.1 Labor market equilibrium

Within a given period, P_t/w_t is determined in the labor market. This is because L and M are exogenous and K_t is pre-determined. Alternatively, there are two main markets: the market for the composite good and the labor market. Market clearing in the labor market therefore implies market clearing of the goods market.

Labor market clearing requires that labor supply equals total labor demand, which we can infer from equation 18:

$$L = \sum_{i=1}^M \left(\frac{(1-\alpha) P_t}{\mu_{it}} \frac{P_t}{w_t} \left(\frac{Q_t}{M} \right)^{1-\eta} a_{it}^\eta k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \quad (62)$$

for a symmetric equilibrium this implies that

$$\frac{P_t}{w_t} = \frac{\mu_{it}}{(1-\alpha)} \left(\frac{L}{K_t} \right)^\alpha = \frac{M-\eta}{(1-\alpha)\eta(M-1)} \left(\frac{L}{K_t} \right)^\alpha \quad (63)$$

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⁴⁴From equation 62, and using that in a symmetric equilibrium $\mu_{it} = \frac{M-\eta}{\eta(M-1)}$:

$$L = \left((1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} \left(\frac{Q_t}{M} \right)^{\frac{1}{\sigma}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \sum_{i=1}^M k_{it}^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}$$

Now, I impose that we are in a symmetric equilibrium, hence $\frac{Q}{M} = \frac{K_t^\alpha L^{1-\alpha}}{M}$; $k_{it} = \frac{K_t}{M}$. Therefore:

$$\begin{aligned} L &= \left((1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} \left(\frac{K_t^\alpha L^{1-\alpha}}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \sum_{i=1}^M \left(\frac{K_t}{M} \right)^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \\ L &= \left((1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} \left(\frac{K_t^\alpha L^{1-\alpha}}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} M \left(\frac{K_t}{M} \right)^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \\ L &= \left((1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} \left(\frac{K_t^\alpha L^{1-\alpha}}{M} \right)^{1-\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} M^{\frac{1-\eta}{1+\alpha\eta-\eta}} K_t^{\frac{\alpha\eta}{1+\alpha\eta-\eta}} \end{aligned}$$

G Model with young firms

Agents The worker side of the model is unaltered from the baseline model. On the firm side, there continues to be an exogenous, finite set M of firm-owners. In this version of the model, heterogeneity across firms arises from the date at which they are born. Before the start of each period, qM new firms are born with capital levels $k_0 \equiv \zeta \frac{K}{M}$, where K is aggregate capital and $0 < \zeta < 1$. At the same time, a set of firms qM dies before the start of the period, such that the total number of firms remains constant.⁴⁵

Firm-owner i has the following intertemporal preferences at time t :

$$U_{it} = \sum_{s=t}^{\infty} (q\beta)^{s-t} d_{is}$$

Where β is the discount factor, q is the ex-ante probability a firm dies in any given period and d_{it} is firm-owner consumption.

Production of varieties Each firm produces a variety i with a Cobb-Douglas production function, using capital k_{it} and labor l_{it} as inputs. There is no variation in productivity across firms.

$$y_{it} = k_{it}^{\alpha} l_{it}^{1-\alpha} \quad (64)$$

Investment $k_{it+1} = x_{it} + (1 - \delta)k_{it}$ is modeled exactly as in the baseline model. The same holds for the definition of the final good, firm-level demand (3), the price index (4), the budget constraint (5), and the financial constraint (6).

G.1 Market structure and optimization in steady state

The market structure and firm-problem are equivalent to the set-up in the baseline model, except that there is no firm-level productivity volatility to be taken into account. Since firms play a one-period game of quantity competition, each firm i sets a quantity y_{it+1} for sale, conditional on the quantities chosen by the other firms in the economy. As discussed in the previous subsection, firms make decisions about l_{it+1}, k_{it+1} in period t , given the budget constraint $P_t(k_{it+1} + d_{it}) \leq z_{it}$. Therefore, any firm i 's optimal decisions are $k_{it+1}(z_{it}, \mathbf{y}_{-it+1})$, $l_{it+1}(z_{it}, \mathbf{y}_{-it+1})$, where (z_{it}) characterizes the state for firm i and \mathbf{y}_{-it+1} is the vector of decisions on y_{jt+1} for all $j \neq i$. Through the production function (64), the choice of k_{it+1}, l_{it+1} determines y_{it+1} and thereby $p_{it+1}(y_{it+1}, \mathbf{y}_{-it+1})$ as firms incorporate the demand function (3)

Taking to the power $1 + \alpha\eta - \eta$

$$L^{1+\alpha\eta-\eta} = \left((1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} \left(\frac{K_t^{\alpha} L^{1-\alpha}}{M} \right)^{1-\eta} \right) M^{1-\eta} K_t^{\alpha\eta} = (\eta - \alpha\eta) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} (K_t^{\alpha} L^{1-\alpha})^{1-\eta} K_t^{\alpha\eta}$$

$$L^{1+\alpha\eta-\eta} = (1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} (L^{1-\alpha})^{1-\eta} K_t^{\alpha}$$

$$L^{1+\alpha\eta-\eta-1+\alpha+\eta-\alpha\eta} = L^{\alpha} = (1-\alpha) \frac{\eta(M-1)}{M-\eta} \frac{P_t}{w_t} K_t^{\alpha}$$

$$\frac{P_t}{w_t} = \frac{1}{(1-\alpha)} \frac{(M-\eta)}{\eta(M-1)} \left(\frac{L}{K_t} \right)^{\alpha}$$

Hence, $\frac{P_t}{w_t}$ is decreasing in M , due to a lower markup.

⁴⁵The ex-ante probability that any firm dies is constant at q , but this probability is not independent across firms as I assume that each period the dying firms hold the same fraction of aggregate capital.

into their optimization. As such, this setting entails the following intertemporal problem for the firm, where $\pi_{it}(k_{it}, l_{it}, \mathbf{y}_{-it}) \equiv p_{it}(y_{it}, \mathbf{y}_{-it})y_{it} - w_t l_{it}$:

$$\begin{aligned} \max_{d_{it}, k_{it+1}, l_{it+1}} \mathcal{L} = & \sum_{t=s}^{\infty} E_s [\beta^{t-s} d_{it}] + \\ & \sum_{t=s}^{\infty} E_s [\lambda_{it} (\pi_{it}(k_{it}, l_{it}, \mathbf{y}_{-it}) + P_t [(1 - \delta)k_{it} - k_{it+1} - d_{it}]) + \Phi_{it}(d_{it})] \end{aligned} \quad (65)$$

Since each firm's decision on y_{it+1} depends on $(z_{it}, \mathbf{y}_{-it+1})$, \mathbf{y}_{it+1} will be determined by $F(z(t))$, the distribution of z_{it} , and by the conditions in the labor and goods market implied by M, L .

$$\begin{aligned} k_{it+1} & (z_{it}, F(z(t)), M, L) \\ l_{it+1} & (z_{it}, F(z(t)), M, L) \end{aligned} \quad (66)$$

From here on, the optimization is exactly as in the baseline model, with equivalent expressions for the demand elasticity, the labor choice and the capital choice.

G.2 Steady state equilibrium

An equilibrium consists of a set of prices P_t, w_t, p_{it} , a set of consumption $d_{it}(z_{it}, F(z(t)))$, capital $k_{it+1}(z_{it}, F(z(t)))$ and labor $l_{it}(z_{it-1}, F(z(t-1)))$ decisions by firm-owners and consumption by workers $\frac{w_t}{P_t}L$ that satisfy

- the labor market clearing condition

$$L = \sum_{i=1}^M l_{it} \quad (67)$$

- the goods market clearing condition

$$Q_t = \sum_{i=1}^M (x_{it} + d_{it}) + \int_{l \in L} c_{it} dl \quad (68)$$

- the optimality conditions for labor and capital for each firm i , conditional on the choices of l_{jt}, k_{jt} of all firms $j \neq i$.
- market-clearing for each variety i : $y_{it} = q_{it}$, satisfying the expression for firm demand.
- the equalized budget constraint $P_t(k_{it+1} + d_{it}) = z_{it}$, and the financial constraint $d_{it} \geq 0$.
- Firms are born with a capital level k_0 . This capital level k_0 , with $k_0 = \zeta k^*$, where k_0 is inherited from the dead firms, such that necessarily $\bar{k} \geq k_0$. And here, $\bar{k} = \frac{K}{M}$. In steady state, we know that $k_0 < k_1$ (i.e. since K is constant, all firms are born with the same k_0 and afterwards grow their capital).

G.3 Steady state conditions

- $K_t = K$
- $P_t/w_t = P/w$
- $F(z(t)) = F(z)$,

An implication of $K_t = K$ is that capital growth by surviving firms will have to equal the capital loss from firms dying.

G.3.1 Labor and capital decisions in steady state

It will again be convenient to characterize the solution to the firm's optimization problem by taking the perspective of the cost-minimization problem given the optimal markup characterized in (9). The cost-minimization problem implies the following optimal labor demand in steady state:

$$l_{it} = \left(\frac{(1-\alpha)P}{\mu_{it}} \frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \quad (69)$$

There are two cases for the firm's capital choice: either $\Phi_{it} = 0$, or $\Phi_{it} > 0$.

Unconstrained firms First consider the case where a firm has $\Phi_{it} = 0$.

$$k^* = \mu_U^{\frac{1}{\eta-1}} \frac{Q}{M} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \left(\frac{\alpha}{r_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \quad (70)$$

with the new definition $r_{it} \equiv \left(\frac{1}{q\beta} + \delta - 1 \right)$ and μ_U the markup of the unconstrained firm.

Constrained firms When the financial constraint binds, i.e. $\Phi_{it} > 0$. Capital grows as allowed by the budget constraint

$$k_{it+1} = (1-\delta)k_{it} + \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \left(\frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \quad (71)$$

This will then imply the following lemma for the capital distribution $H(k)$ in steady state, where τ is the number of periods since the firm was born:

Lemma G.1. *Steady state $H(k)$ is given by:*

- When $\Phi_\tau = 0$, then $k_{i\tau} = k^*$
- When $\Phi_\tau > 0$, then $k_{i\tau} = G_\tau k_0$, where $G_\tau = \prod_{s=0}^{\tau-1} (1 + g_s)$ and $g_s = \frac{k_{is+1}}{k_{is}}$

This way, the capital distribution in this economy is essentially isomorphic to the distribution of the baseline model. Furthermore, the other elements of the system of equations - the markup distribution, TFP , K , $\frac{P}{w}$, Ω - are isomorphic as well, after properly adjusting for the constant productivity. Therefore, this model exhibits analogous comparative statics on M as the baseline model.

H Markup Measurement

Based on De Loecker and Warzynski (2012), setup the Lagrangian for cost-minimization on the variable inputs $X_{it}^1, \dots, X_{it}^V$:

$$L_{it}(X_{it}^1, \dots, X_{it}^V, K_{it}) = \sum_{v=1}^V P^{X_{it}^v} X_{it}^v + r_{it} K_{it} + \lambda_{it} (Q_{it} - Q_{it}(X_{it}^1, \dots, X_{it}^V, K_{it}))$$

$$\text{FOC} : \frac{\partial L_{it}}{\partial X_{it}^v} = P^{X_{it}^v} - \lambda_{it} \frac{\partial Q_{it}(\cdot)}{\partial X_{it}} = 0 \Rightarrow \frac{P_{it}^Y}{\lambda_{it}} = \frac{\partial Q_{it}(\cdot) X_{it}^v}{\partial X_{it} Y_{it}} \frac{P_{it}^Y Y_{it}}{P^{X_{it}^v} X_{it}^v}$$

Which implies:

$$\mu_{it} = \frac{\theta_{it}^{X^v}}{\alpha_{it}^X}$$

- Markup $\mu_{it} \equiv \frac{P_{it}^Y}{\lambda_{it}}$,
- the output elasticity for X^v : $\theta_{it}^{X^v} \equiv \frac{\partial Q_{it}(\cdot)}{\partial X_{it}} \frac{X_{it}}{Q_{it}}$
- X 's expenditure share in total revenue $\alpha_{it}^{X^v} \equiv \frac{P^{X_{it}^v} X_{it}^v}{P_{it} Q_{it}}$.
 - Note that $\mu_{it} = \frac{\theta_{it}^{X^v}}{\alpha_{it}^X}$ holds for any variable input X_{it} .
 - In the majority of the empirical estimations, I use labor as the variable input. In that case, I define $\alpha_{it}^L \equiv \frac{V A_{it}}{w_t l_{it}}$, where $V A_{it}$ is value added.
 - In some robustness checks, I employ materials as the variable input. In that case, I define $\alpha_{it}^M \equiv \frac{S_{it}}{p_t^M M_{it}}$, where S_{it} is sales and $p_t^M M_{it}$ is expenditure of materials.
- For Cobb-Douglas, θ_{it}^X is constant, so all within-sector variation comes from α_{it}^X .

I Further stylized Facts

I.1 Robustness on MRPK dispersion and productivity volatility

In this section, I follow [Asker et al. \(2014\)](#) and implement their plant-level robustness check for examining the relationship between MRPK dispersion and productivity volatility.

Table A.1: MRPK dispersion: plant-level robustness

	MRPK _{irst} (Gross Revenue)				MRPK _{irst} (Value Added)											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
$a_{irst} - a_{irst-1}$	0.723** (0.0182)		0.666** (0.0149)	0.469** (0.0163)	0.565** (0.00490)	0.239** (0.00481)	0.441** (0.00408)	0.172** (0.00480)	1.091** (0.00613)	0.612** (0.0158)	1.053** (0.00300)	0.564** (0.0153)	0.997** (0.00325)	0.250** (0.00592)	0.935** (0.00332)	0.187** (0.00601)
$a_{irst-1} - a_{irst-2}$		0.527** (0.0174)														
a_{irst-1}	0.906** (0.0156)		0.832** (0.0117)	0.682** (0.0139)	0.660** (0.00533)	0.515** (0.00471)	0.515** (0.00471)	0.230** (0.00603)	1.136** (0.00826)	0.863** (0.0140)	1.087** (0.00423)	0.804** (0.0139)	1.017** (0.00380)	0.325** (0.00756)	0.944** (0.00387)	0.252** (0.00764)
k_{irst}		0.756** (0.0151)		-0.199** (0.00491)			-0.479** (0.00480)									
k_{irst-1}				-0.187** (0.00560)				-0.254** (0.00843)								
Plant FE	No	No	No	No	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	Yes
Observations	235765	161861	235765	161861	235765	161861	235765	161861	235765	147713	235765	147713	235765	147713	235765	147713

Standard errors in parentheses

SEs clustered at the sector-level for specifications 1-4, 9-12 and at the plant-level for specifications 5-8, 13-16.

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

I.2 Within-cohort capital misallocation

Table A.2 regresses within-cohort capital misallocation on cohort-age, and we see a significantly negative, though relatively weak, effect. Note that the standard deviation of MRPK is computed only for those firms who survive (write down measure of survival).

Table A.2: Within-cohort Capital Misallocation as a Function of Cohort-Age

	$Std_{cst}(MRPK_{icst}) - VA$			$Std_{cst}(MRPK_{irst}) - GS$		
	(1)	(2)	(3)	(4)	(5)	(6)
age_{cst}	0.000733 (0.00220)	-0.00739 (0.00412)		-0.000897 (0.00210)	-0.00877* (0.00415)	
age_{cst}^2		0.000307* (0.000131)			0.000291* (0.000122)	
$1/age_{cst}$			0.103 (0.0529)			0.165** (0.0586)
Constant	1.087*** (0.0239)	1.111*** (0.0261)	1.063*** (0.0103)	1.086*** (0.0231)	1.111*** (0.0267)	1.033*** (0.0112)
Observations	5945	5945	5764	6468	6468	6276

Standard errors in parentheses

Standard errors clustered at the cohort-sector-level. All specs with cohort-sector FE

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

I.3 Firm Stagnation and Competition

Table A.3: Capital Growth and Competition

	$g(k)_{irst}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Median $\ln(\mu_{rst})$	0.0336*** (0.00341)	0.0298*** (0.00354)	0.0278*** (0.00358)	0.0263*** (0.00365)	0.0226*** (0.00322)		
Median $\ln(\mu_{rst-1})$						0.0201*** (0.00367)	0.0179*** (0.00351)
urban					-0.0177*** (0.00305)		-0.0178*** (0.00309)
age					-0.00308*** (0.000296)		-0.00312*** (0.000312)
age2					0.0000286*** (0.00000460)		0.0000289*** (0.00000476)
Constant	0.0445*** (0.00172)	0.0647*** (0.00460)	0.142*** (0.0116)	0.148*** (0.0114)	0.163*** (0.0104)	0.155*** (0.0123)	0.168*** (0.0110)
State FE	No	No	Yes	Yes	Yes	Yes	Yes
Year FE	No	Yes	No	Yes	Yes	Yes	Yes
Observations	756102	756102	756102	756102	658533	604518	554871

Standard errors in parentheses

All specifications include Sector FE. SEs clustered at state-sector level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table A.4: Difference in markups: urban versus rural

	(1)	(2)	(3)	(4)
	$\ln(\mu) - W$	$\ln(\mu) - W$	$\ln(\mu) - M$	$\ln(\mu) - M$
1(Urban)	-0.110*** (0.0142)	-0.0367** (0.0115)	-0.00568 (0.00473)	-0.0169*** (0.00479)
age		-0.0167*** (0.000957)		0.00253*** (0.000225)
age ²		0.0000742*** (0.0000163)		-0.0000147*** (0.00000285)
Constant	-2.094*** (0.0178)	-1.884*** (0.0240)	0.404*** (0.00541)	0.376*** (0.00679)
Year FE	Yes	Yes	Yes	Yes
Observations	420422	398267	420755	398528

Standard errors in parentheses

SEs clustered at state-sector level. All specifications include Sector-state FEs

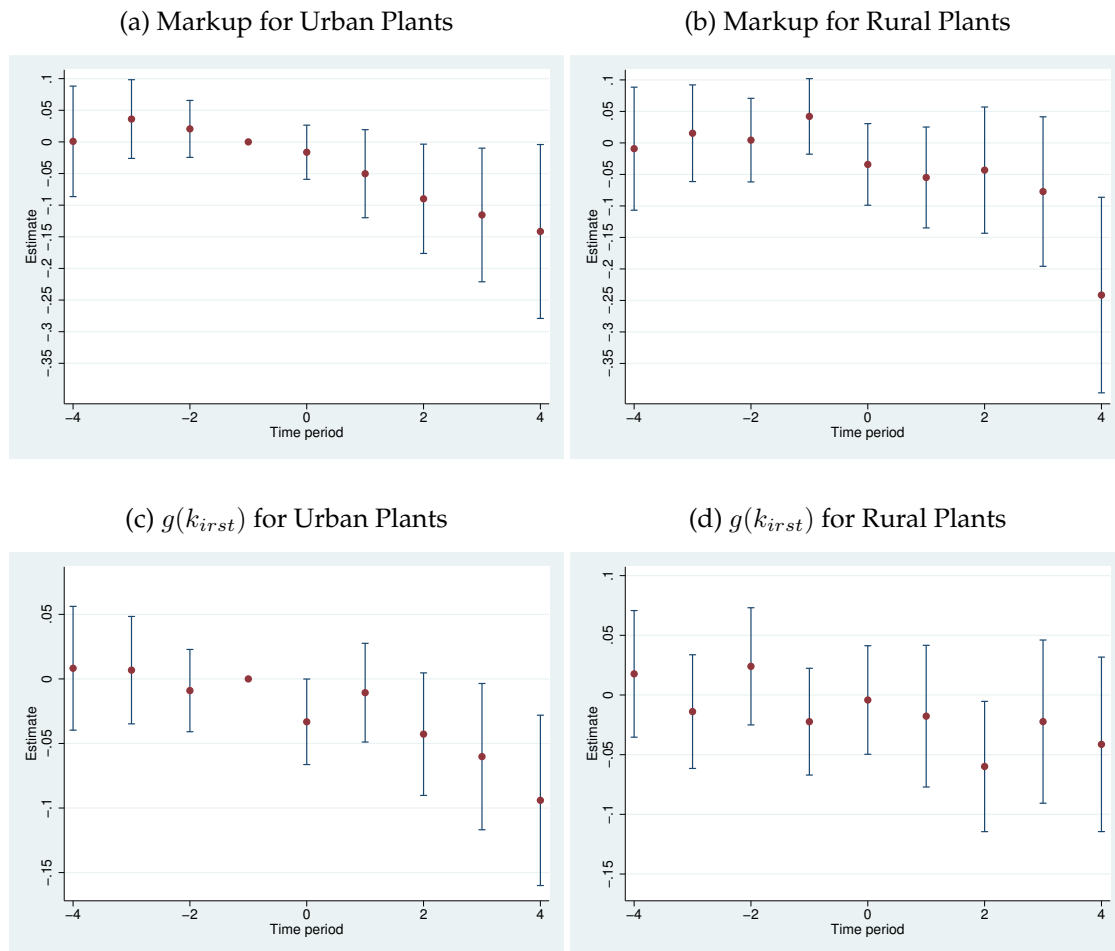
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

I.4 Event Study on Dereservation: Urban/Rural Distinction

$$y_{irst} = \alpha_{rs} + \gamma_t + \zeta 1(Rural_{irs}) + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \sum_{\tau=-4}^4 \beta_{\tau}^R 1(t = \tau) * 1(Rural_{irs}) + \varepsilon_{irst} \quad (72)$$

where $y_{irst} = \mu_{irst}, g(k_{irst})$ and where I bin up the end-points and normalize $\beta_{-1} = 0$. The reason why I investigate heterogeneity for rural plants, is that empirically, baseline markups are lower in an urban setting (see Table G.3). Therefore, an increase in competition might affect internally financed capital growth more for plants in an urban setting. In the empirical tests of the model predictions, the rural/urban distinction will be a relevant, though not essential, dimension of heterogeneity.⁴⁶

Figure 3: Dereservation Event-study on Markup and Capital Growth



The figure displays the coefficients and 95% confidence intervals of an event-study regression on dereservation. Panels (a,b) display the results of the regression $\mu_{irst} = \alpha_{irs} + \gamma_t + \zeta 1(Rural_{irs}) + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \sum_{\tau=-4}^4 \beta_{\tau}^R 1(t = \tau) * 1(Rural_{irs}) + \varepsilon_{irst}$, while panels (c,d) display the results from the following regression: $g(k_{irst}) = \alpha_{rs} + \gamma_t + \zeta 1(Rural_{irs}) + \sum_{\tau=-4}^4 \beta_{\tau} 1(t = \tau) + \sum_{\tau=-4}^4 \beta_{\tau}^R 1(t = \tau) * 1(Rural_{irs}) + \varepsilon_{irst}$. Panels (a,c) display the results for β_{τ} , where I normalize $\beta_{-1} = 0$. Panels (b,d) show estimates for β_{τ}^R .

⁴⁶Note that age and geographic location are almost the only contemporaneous dimensions of exogenous heterogeneity for incumbent plants. As such, analyzing heterogeneous treatment effects along this dimension is a valid empirical exercise.

J Financial Dependence

J.1 Effect on average growth rate - firm growth and financial dependence

The main empirical section contains tests closely related to the theoretical channels (MRPK convergence and growth for young plants.) From a more reduced form perspective, one can also just look at the relationship between firm-growth, the median markup and financial dependence. Here, the results are consistent with the results on convergence in the more structural equations in the financial dependence section in the main paper.

Table A.5: Capital Growth and Competition

	(1)	(2)	(3)	$g(k)_{irst}$		(6)
				(4)	(5)	
Median $[\ln \mu_{rst}]$	0.0308*** (0.00591)	0.0261*** (0.00554)	0.0210*** (0.00487)			
Median $[\ln \mu_{rst-1}]$				0.0213*** (0.00601)	0.0188*** (0.00548)	0.0180*** (0.00500)
$Median_{rst}[\ln \mu_{irst}] * Fin Dep_s$	0.0259** (0.00893)	0.0138 (0.00799)	0.0194* (0.00784)			
$Median_{rst}[\ln \mu_{irst-1}] * Fin Dep_s$				0.0245** (0.00929)	0.0163 (0.00852)	0.0130 (0.00822)
Controls	No	No	Yes	No	No	Yes
State FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Observations	638701	638701	558922	512756	512756	471868
Nr of Clusters	3989	3989	3920	3079	3079	3073
R^2	0.0117	0.0161	0.0183	0.0109	0.0157	0.0184

Standard errors in parentheses

All specifications include Sector FE. SEs clustered at state-sector level since Fin Dep and median μ measured at that level.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

K Capital-labor ratio convergence

The main proposition in the theory section predicts that capital wedges shrink faster in a market with lower levels of competition. In this appendix section, I present additional evidence for this prediction, arising from the convergence of plant-level capital-labor ratios to their optimal level.

From the expressions in the theory section, combining the expression for optimal labor choice:

$$l_{it} = \mu_{it}^{\frac{1}{\eta-1}} \frac{Q}{M} a_{it}^{\frac{\eta}{1-\eta}} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{1-\eta+(1-\alpha)\alpha\eta^2}{(1-\eta)(1+\alpha\eta-\eta)}} \left(\frac{\alpha}{\omega_{it}} \right)^{\frac{\alpha}{1-\eta}} \quad (73)$$

and equation (25) for optimal capital choice, one can find that the capital labor ratio takes the following form:

$$\frac{k_{it}}{l_{it}} = \frac{(1 - \alpha)\alpha P}{\omega_{it} w} \quad (74)$$

As such, theoretically the only source of variation in $\frac{k_{it}}{l_{it}}$ across firms within a sector arises from the capital wedges ω_{it} . In the table below I test whether the speed of convergence of the capital-labor ratio is faster in settings with less competition. The data again confirm this prediction of the model.

Table A.6: Capital-labor ratio: speed of convergence

	$\left(\frac{k}{l}\right)_{irst}$	
	(1)	(2)
$\left(\frac{k}{l}\right)_{irst-1}$	0.337**	0.315**
	(0.00472)	(0.00714)
$\left(\frac{k}{l}\right)_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}]$	-0.0216**	-0.00221
	(0.00548)	(0.00885)
$\left(\frac{k}{l}\right)_{irst-1} * Fin Dep_s$		-0.0109
		(0.0132)
$\left(\frac{k}{l}\right)_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] * Fin Dep_s$		-0.0290
		(0.0162)
Influence of $Median_{rst-1}[\ln \mu_{irst-1}]$ on convergence speed:		
$\rho_1 * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$	-0.0407	-0.0042
$[\rho_1 + \rho_3 * Fin Dep_s(90\%ile)] * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$		-0.0461
Plant FE	Yes	Yes
State-sector-year FE	Yes	Yes
Observations	237344	193016

Standard errors, clustered at the plant-level, in parentheses (* $p < 0.05$, ** $p < 0.01$). The variable $\left(\frac{k}{l}\right)_{irst}$ is the firm-level capital-labor ratio, in logs. The inverse measure for competition, $Median_{rst}[\ln \mu_{irst}]$, is demeaned within sectors. Both specifications include a cubic polynomial in age as control variables.

$90\%ile[Median(\ln \mu)]$ and $10\%ile[Median(\ln \mu)]$ are the respective values for the 90th and the 10th percentile of $Median_{rst-1}[\ln \mu_{irst-1}]$ across state-sector-year observations. This way, $\rho_1 * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$ reports the difference in average convergence rate for firms exposed to the value of the median markup in the respective percentiles. In specification (2), this is for firms in sectors with 0% financial dependence.

$90\%ile[Median(\ln \mu)] * [\rho_1 + \rho_3 * Fin Dep_s(90\%ile)] - 10\%ile[Median(\ln \mu)] * [\rho_1 + \rho_3 * Fin Dep_s(90\%ile)]$ reports the difference in average converge rates, due to different median markups, for firms producing in sectors at the 90th percentile of financial dependence