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

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Abstract

This paper develops a novel general-equilibrium model of the relationship between competition, financial constraints and misallocation, and tests its implications using Indian plant-level panel data. In the model, steady-state misallocation consists of both variable markups and capital wedges. The variable markups arise from Cournot-type competition, whereas the capital wedges result from the interaction of firm-level productivity volatility with financial constraints. Firms experience random shocks to their productivity and in response to positive productivity shocks 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 is associated with slower capital accumulation, as the rate of self-financed investment falls. 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, measured capital misallocation, which motivates this paper's analysis, can be explained by technological constraints, market imperfections or policy distortions, amongst others.[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 (Peters, 2013) explains how in a setting with variable markups, competition reduces misallocation by decreasing dispersion in markups.[2] While such a channel is still present in my analysis, I demonstrate that financial constraints introduce a second, negative impact of competition on misallocation. Specifically, I show that competition slows down the capital growth rate of financially constrained firms. Thereby, capital wedges, which result from the difference between the optimal and the actual capital level of a firm, are amplified by competition. The intuition for this result is that firm-level markups fall with the degree of competition, which lowers the rate of internally financed capital growth. 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 in this context means 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. A financially constrained firm will therefore rely on internally financed capital growth, which will imply that the firm's capital growth is a function of its markup. Since the firm's capital growth rate depends on its markup, its speed of convergence to its optimal level of capital will also depend on the markup. Increased competition, by reducing a firm's

[1]Roughly speaking, measured 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 *mis*allocation of capital. In other settings measured dispersion in MRPK arises from market imperfections or policy distortions. In the models presented by Midrigan and Xu (2014) and Moll (2014), capital misallocation is driven by firm-level collateral constraints, which 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, which results from e.g. a non-competitive banking sector varying its interest rates for noneconomic reasons. Restuccia and Rogerson (2013) provide a broader survey of the misallocation literature, while Buera et al. (2015) survey the literature on the macro-economic impact of financial constraints.

[2]In an earlier contribution, Epifani and Gancia (2011) demonstrate that trade liberalization can have ambiguous effects on markup misallocation. In their setting, misallocation arises from differences in the degree of competition across industries, whereas I focus on varying the degree of competition within a single industry.

markup, will then negatively affect its 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. I present this channel in a version of the model where there is no productivity volatility but instead there is birth and death of firms. If newborn firms are undercapitalized and therefore financially constrained, 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 and thereby amplifies capital wedges.[3]

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 with productivity volatility as it focuses directly on plant-level MRPK, where, inspired by Asker et al. (2014), plant-level deviations in MRPK serve as a proxy for 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 individual plant's point of view, namely the median markup measured at the state-sector-year level. The advantage of this approach is that I can test the theory on a large set of Indian manufacturing plants, while a potential limitation is that the underlying structural drivers of the variation in the 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. After demonstrating the pro-competitive impact of the dereservation reform on incumbent plants, I now test whether after the reform, MRPK convergence and capital growth of young plants is slower.[4] The data again confirm the two predictions of the model.

[3] I provide evidence that productivity volatility and the birth of newborn firms are both contributing to capital misallocation in the Indian manufacturing sector.

[4] The 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

The theory builds on Midrigan and Xu (2014), who examine comparative statics for steady-state capital misallocation in a setting of imperfect competition. The main focus of Midrigan and Xu (2014) is on quantifying the relative importance of barriers to entry for new firms versus collateral constraints for incumbent firms in shaping misallocation. My focus on the comparative statics for competition is therefore complementary to their analysis. Moreover, I analytically derive general theoretical results, whereas Midrigan and Xu (2014) rely on simulation-based methods. Interestingly, the steady state in my model is determined by a system of non-linear equations, which does not allow for a closed-form solution to the comparative statics exercise. Instead, I derive such a solution by exploiting the logical properties of the steady state equilibrium.

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 competition on misallocation. This difference in market structure not only makes our analyses complementary, it also modifies the theoretical solution strategy because a closed-form solution is available under perfect competition, but not under imperfect competition.

By examining the potential downsides of intensified competition, this paper complements papers that emphasize the beneficial impacts of competition on misallocation.[5] 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). Such 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). In this paper, I aim 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. Existing stylized facts strongly suggest that both productivity volatility and entry of newborn firms, two possible sources of misallocation in a setting with financial constraints, are potentially important for misallocation 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

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.

[5] In the innovation literature, it is well-established that increasing competition can have both positive and negative impacts on aggregate output (see e.g. Aghion et al. (2005, 2013); Gilbert (2006)). Also in the empirical micro-development literature there is work that studies the downsides of competition (Macchiavello and Morjaria, 2015). However, in the misallocation literature, the downsides of misallocation have been understudied.

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.

2 Theory

2.1 Setup of the economy

Agents The economy has two types 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_{lt} is hand-to-mouth.

There is an exogenous, finite set M of firm-owners.[6] Firm-owner i has the following intertemporal preferences at time s:

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

Where β is the discount factor and d_{it} is firm-owner consumption.[7]

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:

$$y_{it} = a_{it} k_{it}^{\alpha} l_{it}^{1-\alpha} \tag{1}$$

Productivity a_{it} follows a stochastic process over the state space $a_{it} \in \{a_L, a_H\}$, where $a_L < a_H$.[8] 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. Importantly, 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 $t+1$.[9]

[6] The 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.

[7] The 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.

[8] Increasing the dimensionality of the state space would add substantial complexity to the comparative-statics exercise, without yielding additional economic insight. I follow Midrigan and Xu (2014) by assuming that in period t, the firm is informed about the distribution of a_{it+1}.

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

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

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

where $M^{1-\frac{1}{\eta}}$ eliminates taste-for-variety (Blanchard and Kiyotaki, 1987).[10] [11] This expression for the composite good implies that firms face the following demand function q_{it}:

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

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

$$P_t^{-\frac{\eta}{1-\eta}} \equiv \frac{1}{M} \sum_{i=1}^{M} p_{it}^{-\frac{\eta}{1-\eta}} \tag{4}$$

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: $z_{it} \equiv p_{it}y_{it} - w_t l_{it} + P_t(1-\delta)k_{it}$.

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

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

$$d_{it} \geq 0 \tag{6}$$

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.[12] 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, knowing a_{it+1} and given the budget constraint $P_t(k_{it+1} + d_{it}) \leq z_{it}$. Therefore, any firm i's optimal decisions are $k_{it+1}(a_{it+1}, z_{it}, \mathbf{y_{-it+1}})$, $l_{it+1}(a_{it+1}, z_{it}, \mathbf{y_{-it+1}})$, 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 optimiza-

[10] This 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 the idea of de-linking consumption-side taste-for-variety and firm-level market power.

[11] There 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 shares are constant across sectors in that case.

[12] I will assume that strategic interaction of firms is only within-period.

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

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

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.

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

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

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

where the demand elasticity ε_{it} is:

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

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

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

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:

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

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

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

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:[13]

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

  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 $t+1$:

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

- **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 (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

$$L = \sum_{i=1}^{M} l_{it} \tag{15}$$

- the goods market clearing condition

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

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

- 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 Mx3 equations with Mx3 unknowns.

A *steady state equilibrium* is an equilibrium that satisfies for all t[14] :

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

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.[15] 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 $F(a+1, z)$. Here, the wealth distribution is endogenous, whereas the distribution of productivities is exogenously determined. Since the distribution of wealth is a function of $H(a, k)$, I focus on examining this joint distribution of productivities and capital in steady state. To this end, 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

[14] Moll (2014) employs a similar definition of a steady state equilibrium.

[15] The assumptions on the productivity volatility process, described in Appendix C, are such that the productivity volatility process allows for a stable $H(a, k)$.

(9).[16] As such, the cost-minimization problem implies the following optimal labor demand in steady state:

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

For the capital choice, as is clear from section 2.2.1, there are two cases: 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

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

where $r_{it}\equiv\left(\frac{1}{\beta}+\delta-1\right)-\xi_{it}$.[17]

Constrained firms When the financial constraint binds, i.e. $\Phi_{it}>0$. Capital grows according to the budget constraint. Specifically, I show in appendix B.2 that:

$$k_{it+1}=(1-\delta)k_{it}+\left[\mu_{it}-(1-\alpha)\right]\frac{w_t}{P_t(1-\alpha)}l_{it} \tag{20}$$

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 $\Phi_{it}>0$[18], 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 $\tau=t-s$,

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

and

$$g_r\equiv\frac{k_{r+1}}{k_r}-1;\ s\equiv\max r\ \text{s.t.}\ a_{ir+1}=a_H\&a_{ir}=a_L$$

Here, k_{r+1} is determined by (20), for any firm i with capital level k_r. In words, k_{it} is determined by the cumulative capital growth G_τ since the firm's most recent positive productivity shock.

[16] Jaimovich (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.

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

[18] Suppose 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 $F(a(t+1),k(t))=F(a',z)$.

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

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

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 $a_{it} = a_L$. Since for firms with $a_{it} = a_H$, the level of capital depends on G_τ, the value of Φ_{it} is also determined by τ, i.e. the number of periods since the most recent productivity shock. The above entails that the following lemma holds.

Lemma 1. *Steady state $H(a,k)$ is determined by:*

- *if $a_{it} = a_L$, then $k_{it} = k_L^*$*
- *if $a_{it} = a_H$ 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 $k_{i\tau} = G_\tau k_L^*$*

2.4.3 Distribution of markups

Now, I characterize the distribution of markups. First, the markups for the unconstrained firms follow directly from (9), (10) and Lemma 1.

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

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

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

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

2.4.4 Capital wedges

Next, I analyze the capital wedges ω_{it}, which will be important in the analysis of aggregate TFP. The capital wedges are implicitly defined in the following way:

$$k_{it} = \left(\frac{a_{it}^{\eta}}{\mu_{it}}\right)^{\frac{1}{1-\eta}} \left(\frac{\alpha}{\omega_{it}}\right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \left(\frac{P(1-\alpha)}{w}\right)^{\frac{\eta-\alpha\eta}{1-\eta}} \frac{Q}{M} \tag{25}$$

where $\omega_{it} = r_L, r_H$ for unconstrained firms with productivities a_L, a_H respectively, and $\omega_{it} > r_H$ for constrained firms. For these constrained firms, I combine equations (22) and (25), to express the capital wedge for any period τ:[19]

$$\omega_\tau = G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^{\eta}}{a_L^{\eta}} \frac{\mu_L}{\mu_\tau}\right]^{\frac{1}{1+\alpha\eta-\eta}} r_L \tag{26}$$

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

Lemma 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* $\Phi_\tau = 0$, $\omega_{it} = r_H$
  - *When* $\Phi_\tau > 0$, $\omega_\tau(G_\tau, \mu_\tau) = G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^{\eta}}{a_L^{\eta}} \frac{\mu_L}{\mu_\tau}\right]^{\frac{1}{1+\alpha\eta-\eta}} r_L$

2.4.5 Aggregates for output, capital and TFP

Aggregate output In appendix A.1, I show that

$$Q = TFPK^{\alpha}L^{1-\alpha} \tag{27}$$

where TFP is aggregate productivity and K is aggregate capital.

TFP I now characterize TFP. In appendix A.1, I derive equation (46), 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}. Since the capital wedges are a function of a_{it}, k_{it}, I can use Lemma 1 and equations (23),(24), to characterize TFP as:

$$TFP = F_{TFP}(H(a,k), M) \tag{28}$$

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

Aggregate capital Given Lemma 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: [20]

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

2.5 Labor Market clearing

Since there are 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:

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

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

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

where

$$\Omega \equiv \left[\sum_{i=1}^{M}\left(\frac{a_{it}^\eta}{\mu_{it}}\left(\frac{\left(\frac{a_{it}^\eta}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}}\right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^{M}\left(\frac{a_{it}^\eta}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}}\right)^{\frac{1}{1-\eta}}}\right)^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}}\right] \tag{31}$$

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.

[20] Specifically:

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

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

$$\frac{P}{w} = F_L(M, L, K, TFP, \Omega) \tag{32}$$

2.5.1 Summary of steady-state equilibrium

The nature of the steady-state equilibrium will be determined by the following elements:

- $H(a, k)$, the joint distribution of a_{it}, k_{it}, characterized in Lemma 1
- The distribution of markups, characterized in equations (23), (24)
- Aggregate TFP, characterized in (28)
- Aggregate capital, characterized in (29)
- The factor-price ratio, determined in the labor-market-equilibrium condition in (32)
- Ω, characterized in (31).

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 is a crucial determinant of 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 1. *For any $M' > M$, and for unconstrained firm-types L, H, and for constrained firms in period $\tau > 0$:*

- *Markup levels fall with M:*
$$\mu'_L < \mu_L \,;\, \mu'_H < \mu_H \,;\, \mu'_\tau < \mu_\tau$$
- *Markup dispersion falls with M:*
$$\frac{\mu'_H}{\mu'_L} < \frac{\mu_H}{\mu_L} \,;\, \frac{\mu'_\tau}{\mu'_L} \leq \frac{\mu_\tau}{\mu_L}$$
- *Capital wedges worsen with M:*
$$\omega'_\tau \geq \omega_\tau$$
and $(\Phi_\tau > 0) \implies (\omega'_\tau > \omega_\tau)$

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.[21] 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.[22]

In 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 convenience, I will be referring to both geographical units as "states."[23]

3.1 Variable definitions

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

The empirical analysis will provide both motivating macro-level stylized facts, as well as micro-level evidence on capital convergence. Both sections of the empirical discussion will examine data-patterns related to plant-level capital growth, marginal revenue product of capital and markups. I now describe the construction of these main variables. First, capital growth is measured as:[24]

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

Second, marginal revenue product of capital (MRPK) is measured as in Asker et al. (2014), who assume a sector-level Cobb-Douglas production function, which implies that the marginal revenue product of capital takes the following form:

[21] The particulars provided here hold for the majority of the sample years. Bollard et al. (2013) provide a more detailed description of the ASI data, including certain modifications to the sampling scheme.

[22] For 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.

[23] To make the definitions of states consistent over time, I employ the concordance provided by the Indian Statistical Office. This results in a number of 35 states in the panel data.

[24] Here, K_{irst+1} is the book value of assets at the end of the financial year.

$$MRPK_{irst} = \ln(\beta_s^K) + s_{irst} - k_{irst} \tag{33}$$

Here, I also employ a value-added measure for MRPK as a leading robustness check, where $MRPK_{irst}^{VA} = \ln(\beta_s^{K,VA}) + va_{irst} - k_{irst}$.

Proposition 1 states an increase in M leads to a decrease in the markup for any type of firm. As such, the model entails that any first moment of the distribution of markups falls with the degree of competition. Since the median is a robust first moment, I choose $Median_{rst}[\ln \mu_{irst}]$ as the primary, inverse measure of competition at the state-sector-year level, where μ_{irst} is the plant-level markup. The measurement of μ_{irst} follows the procedure outlined by De Loecker and Warzynski (2012), and is discussed in appendix E. In particular, I assume plants have Cobb-Douglas production functions, minimize costs, and that labor is a variable input. Together, these assumptions imply the following expression for μ_{irst}:

$$\mu_{irst} = \beta_s^L \frac{VA_{irst}}{w_{irst} L_{irst}} \tag{34}$$

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

4 Stylized facts

This section first provides support for the empirical relevance of the main model assumptions, and second, presents motivating evidence in support of a central macro-level prediction of the model. To be clear, the current section does not aim to provide causal evidence. However, the next section will aim to establish a causal link between competition and plant-level capital convergence, in support of the model's predicted negative role of competition.

4.1 Validation of model assumptions

In this subsection I provide stylized facts that provide support for the empirical relevance of the assumptions that are central for generating misallocation in the two versions of the model. In one version of the model, capital misallocation arises from the interaction of financial constraints with productivity volatility. A first stylized fact will demonstrate a strong correlation between a measure for capital misallocation and measured productivity volatility. This is consistent with productivity volatility being an important driver of capital misallocation. In the second version of the model, capital misallocation arises from the birth of undercapitalized firms. The second stylized fact will document elevated capital growth for young plants, which will therefore corroborates the empirical relevance of the second version of the model.

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.[25] 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.[26] To provide further evidence on the empirical relevance of productivity volatility and to set the stage for the capital convergence analysis in the next section, I replicate the analysis from Asker et al. (2014) for the ASI data. Here, MRPK dispersion will be measured at the sector-year level:

$$\text{MRPK Dispersion} = Std_{st}(MRPK_{irst})$$

And the empirical measure for productivity volatility is

$$\text{Productivity Volatility} = Std_{st}(a_{it} - a_{it-1}),$$

where a_{it} is the measure of plant-level productivity. Here, a_{it} is measured as in Asker et al. (2014), who impose 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:

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

where $\beta_s^L = Median_s \left[\frac{wage\, bill_{irst}}{S_{irst}}\right]$, $\beta_s^M = Median_s \left[\frac{M_{irst}}{S_{irst}}\right]$, $\beta_s^K = 1 - \beta_s^L - \beta_s^M$. In addition, I also use a measure of productivity based on value-added:[27] $a_{irst}^{VA} = va_{irst} - \beta_s^{K,VA} k_{irst} - \beta_s^{L,VA} l_{irst}$, with $\beta_s^{L,VA} = Median_s \left[\frac{wage\, bill_{irst}}{VA_{irst}}\right]$; $\beta_s^{K,VA} = 1 - \beta_s^{L,VA}$.[28] [29]

In Figure 1, we see that there is a strong upward sloping relationship between productivity

[25] Asker et al. (2014) provide a model with capital adjustment-costs, instead of financial constraints, that also leads to delayed adjustment of capital and therefore to dispersion in MRPK. Importantly, 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 MRPK dispersion being driven by capital adjustment-costs, the evidence in the next sections, centered around the relation between capital convergence and competition, is not captured by an explanation based on adjustment costs.

[26] Asker et al. (2014) document that this relationship holds within the Prowess dataset in India. Since Prowess features firms registered on the stock market, and consists therefore of a smaller sample than the ASI, the empirical analysis here is a useful complement to their analysis.

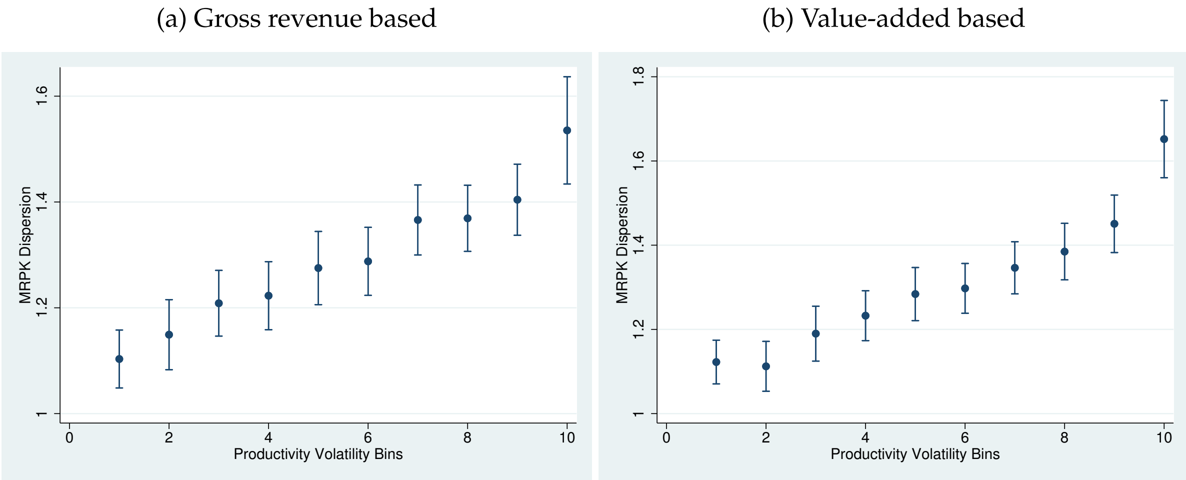
[27] Where value added is measured as: $VA_{irst} = S_{irst} - M_{irst}$

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

[29] 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.

volatility and MRPK dispersion, for both the gross-revenue based measure, and for the value-added based measure. This empirical relationship corroborates the relevance of the theoretical model.[30]

Figure 1: Productivity volatility and MRPK dispersion



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 $Std_{st}(MRPK_{irst}) = \sum_{D=1}^{10} \gamma_D 1(Decile\ D)_{st} + \varepsilon_{st}$, and plot the values for the coefficients and 95% confidence intervals of γ_D.

4.1.2 Age and Capital Growth

In an extension of the model, described in appendix D, I assume that firms are born with suboptimally low levels of capital. The firms' optimizing behavior then implies that, after they are born, they grow their capital to its optimal level and then remain at that capital level until they die. In this subsection, I examine whether it is empirically true in the ASI data that young plants exhibit higher capital growth rates than older plants.[31] [32]

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 specifications 5-8, as capital growth is higher for plants not older than 5 or younger than 10 years.

[30] In appendix F.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.

[31] The existing empirical literature provides extensive support for this stylized fact, see e.g. Evans (1987); Geurts and Van Biesebroeck (2014); Haltiwanger et al. (2013). I here test its validity for the Indian manufacturing sector.

[32] Another relevant stylized fact relates to within-cohort capital misallocation. If there is heterogeneity across plants in capital or productivity levels at the time of their birth, translating immediately in heterogeneity in MRPK, one would expect this dispersion in MRPK to decline with age. This pattern is observed in Table **??**, and discussed in appendix F.

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**	0.140**						
	(0.00412)	(0.00569)						
$\ln(\frac{1}{age_{irst}})$			0.0136**	0.0357**				
			(0.00108)	(0.00169)				
$1(age_{irst} \leq 5)$					0.0597**	0.0576**		
					(0.00210)	(0.00281)		
$1(age_{irst} < 10)$							0.0369**	0.0306**
							(0.00190)	(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

Proposition 1 states that capital wedges increase when the degree of competition is more intense. In this section, I aim to provide suggestive evidence that empirically, increased competition is associated with higher levels of measured capital misallocation. Here, the measure for capital misallocation is again the Asker et al. (2014) measure for MRPK dispersion. The regression analysis employs the following specification:

$$Std_{rst}(MRPK_{irst}) = \gamma_s + \gamma_t + \gamma_r + \zeta Median_{rst}[\ln \mu_{irst}] + \epsilon_{rst} \tag{35}$$

In this specification $Median_{rst}[\ln \mu_{irst}]$ is the inverse measure of competition, $\gamma_s, \gamma_t, \gamma_r$ are sector, year and state fixed effects respectively. In alternative specifications, I also run this regression without γ_t, γ_r. However, I always include γ_s to eliminate variation arising from the measurement of β_s^L, the output elasticity for labor which is measured at the sector level.

Results Table 2 provides suggestive evidence for the prediction that MRPK dispersion might increase with competition. 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.[33]

[33] One might be worried about a mechanical correlation between the level of $Median_{rst-1}[\mu_{irst-1}]$ and the level of $Std_{rst}(MRPK_{irst})$. Note, however, that this would imply a positive correlation, while the regressions in Table 2 demonstrate 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**	-0.0494**	-0.0371**	-0.0353**	-0.0501**	-0.0447**	-0.0376**	-0.0353**
	(0.0102)	(0.0101)	(0.0102)	(0.0101)	(0.00977)	(0.00972)	(0.0101)	(0.00997)
Constant	1.306**	1.236**	1.257**	1.228**	1.321**	1.438**	1.336**	1.477**
	(0.00487)	(0.0125)	(0.0329)	(0.0347)	(0.00465)	(0.0291)	(0.0362)	(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 above evidence suggests that increased competition might worsen macro-level capital misallocation. The next empirical section will investigate the underlying micro-dynamics for the relation between competition and capital misallocation. To this end, I will examine if the model predictions on the negative link between firm-level speed of convergence and competition are observed in the data.

5 Competition and capital convergence

This section first explains the empirical counterparts for the model predictions, and then tests these predictions in the ASI data.

5.1 Empirical predictions

Proposition 1 summarizes the dual role for competition in the model. Since the positive role for competition is relatively standard in the literature - e.g. Peters (2013), Schaumans and Verboven (2015) - I focus here on testing the empirical presence of the negative role of competition. This negative role for competition consists in amplified capital wedges for any type of financially constrained firm in the model. These amplified capital wedges arise from slower capital growth for financially constrained firms, and therefore slower firm-level convergence to the optimal level of capital. In this section I describe the empirical tests for increased competition leading to slower capital convergence. A first set of empirical tests examines convergence in marginal revenue product of capital (MRPK), while a second set of tests examines capital growth for young plants.

Competition For both sets of empirical tests, the state-sector-year level median markup, i.e. $Median_{rst}[\ln \mu_{irst}]$, will again serve as the inverse measure of competition. Since this competition measure is arguably exogenous from the plant's point of view, this allows me to examine the causal link between competition and the empirical measures for plant-level capital convergence. Although the empirical tests will not be able to examine macro-level capital misallocation directly, an important advantage of these tests is that they can be implemented on the full panel of plants in the ASI data.

MPRK convergence In the baseline model, firms optimally choose to grow their capital stock in response to positive productivity shocks until they reach k_H^*, the optimal level of capital for high productivity firms. The empirical challenge here is that k_H^* is unobserved. To address this challenge, I focus on convergence in terms of marginal revenue product of capital (MRPK).

In terms of MRPK, the inability for a financially constrained firm to satisfy the unconstrained first-order condition in (14) implies that for this firm, $MRPK_{it}^* < MRPK_{it}$. Here $MRPK_{it}$ is firm i's actual MRPK in period t, and $MRPK_{it}^*$ is its optimal MRPK from the unconstrained solution. Since $MRPK_{it}$ is a strictly monotone function of k_{it}, and capital convergence in the model slows down with M, MRPK convergence also slows down with M. This is then 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 proxy for $MRPK_{it}^*$, which then allows me to analyze how convergence to $MRPK_{it}^*$ changes with the degree of competition.

Young plants In appendix section D, I show that a model with birth of newborn firms is 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. The empirical advantage of this version of the model is that it allows me to test the model predictions on capital growth for young plants, which is a reduced-form object in the data.

Financial Dependence In an additional set of tests I explore the implications of heterogeneity along financial dependence for both MRPK convergence and capital growth for young plants. Here, the idea is that for sectors with higher levels of financial dependence, measured as $Fin\ Dep_s$, changes in the level of sector-level competition have a stronger impact on the rate of MRPK convergence.

Empirically, $Fin\ Dep_s$ will be 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 sectors in the 1980's.[34] Here, $Fin\ Dep_s$ 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. The central idea in Rajan and Zingales (1998) is then that in a setting such as India, with less developed financial markets, financial constraints become especially binding in sectors with high levels of $Fin\ Dep_s$.

[34] I 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.

5.2 Econometrics

MRPK convergence To implement the empirical test on MRPK convergence, I use the following autoregressive framework.[35]

$$MRPK_{irst} = \alpha_{irs} + \rho_0 MRPK_{irst-1} + \rho_1 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] + \beta X_{irst} + \gamma_t + \varepsilon_{irst} \tag{36}$$

The main coefficient of interest in this specification is ρ_1. This coefficient estimates how the speed of convergence changes as a function of $Median_{rst-1}[\ln \mu_{irst-1}]$.[36] 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 proxy for $MRPK^*_{irst}$, i.e. $E[MRPK_{irst}|(\rho_0 = \rho_1 = 0)] = MRPK^*_{irst}$, regardless of $MRPK_{irst-1}$.

In practice, we will find that $0 < \rho_0 + \rho_1 < 1$ and $\rho_0 > \rho_1$, such that on average plants experience a delayed adjustment to the proxy for $MRPK^*_{irst}$. 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 $MPRK^*_{irst}$. A first specification is $MPRK^*_{irst} = \alpha_{irs} + \beta X_{irst} + \gamma_t$, as indicated in specification 36, and a second measure is $MRPK^*_{irst} = \alpha_{irs} + \alpha_{rst} + \beta X_{irst}$. 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.[37] Throughout, the vector of control variables X_{irst} consists of a quadratic polynomial in age_{irst}.

Financial dependence To examine the role of financial dependence in the setting of MRPK convergence, I augment the earlier specifications to allow for heterogeneous effects along financial dependence:

$$\begin{aligned} MRPK_{irst} = {} & \alpha_{irs} + \rho_0 MRPK_{irst-1} + \rho_1 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] \\ & + \rho_2 MRPK_{irst-1} * Fin\ Dep_s + \rho_3 MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}] * Fin\ Dep_s \\ & + \beta X_{irst} + \gamma_t + \varepsilon_{irst} \end{aligned} \tag{37}$$

[35]Since $MRPK_{irst-1} * Median_{rst-1}[\ln \mu_{irst-1}]$ varies at the plant-level, standard errors will be clustered at the plant level in specifications 36, 37.

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

[37]To 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.

For this specification, the expectation is that $\rho_3 < 0$, as a decrease in competition would speed up convergence more for plants in sectors with higher levels of financial dependence.

Young plants The model with undercapitalized newborn plants yields empirical predictions on the capital growth for young plants. Since these predictions can be tested directly on the capital growth for young plants, a reduced-form object in the data, these tests are a useful complement to the autoregressive framework in the setting with MRPK convergence. To implement these tests, I run the following regression:[38]

$$g(k_{irst}) = \alpha_{rst} + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \varepsilon_{irst} \tag{38}$$

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 (37), to examine the heterogeneous effect of $Median_{rst}[\ln(\mu_{irst-1})]$ for young firms' capital growth in sectors with higher levels of financial dependence[39]:

$$\begin{aligned} g(k_{irst}) =& \alpha_{rst} + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} \\ &+ \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} * Fin\ Dep_s + \varepsilon_{irst} \end{aligned} \tag{41}$$

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

5.3 Results

MRPK Convergence Table 3 provides the estimation results for specifications (36) and (37), and these results 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 predicts that there is convergence to $MRPK^*_{irst}$ ($|\rho_0| < 1$) but that this convergence is not immediate ($\rho \neq 0$) due to financial constraints. Also note that across all specifications, the coefficient estimate for ρ_0 is on the low side. More specifically, the half-life of a deviation from $MRPK^*_{irst}$ is generally lower than 1 year. Note that this fast convergence rate lends empirical support to the choice of the proxy for $MRPK^*_{irst}$.

[38]For specifications 38, 41 standard errors will be clustered at the sector level.

[39]In addition to specifications (38), (41), I will also estimate:

$$g(k)_{irst} = \alpha_{irs} + \gamma_t + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] + \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} + \varepsilon_{irst} \tag{39}$$

$$\begin{aligned} g(k_{irst}) =& \alpha_{irs} + \gamma_t + \beta_1 young_{irst} + \beta_2 Median_{rst}[\ln(\mu_{irst-1})] + \beta_3 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} \\ &+ \beta_4 Median_{rst}[\ln(\mu_{irst-1})] * Fin\ Dep_s + \beta_5 Median_{rst}[\ln(\mu_{irst-1})] * young_{irst} * Fin\ Dep_s + \varepsilon_{irst} \end{aligned} \tag{40}$$

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

The focus of this empirical section is on testing the model's prediction on how competition affects the speed of convergence. For the estimated specifications, the speed of convergence always increases with $Median_{rst}[\ln(\mu_{irst-1})]$. Columns (1,2,5,6) provide the results on the baseline specifications and show that the coefficient on ρ_1 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.

Columns (3,4,7,8) show the results for the tests exploring heterogeneity along sectoral financial dependence. As expected, the coefficient ρ_3, estimated on the triple interaction term, is always negative. Moreover, this coefficient estimate is strongly statistically significant in columns (3,4,7).[40] [41] The estimation result that $\rho_3 < 0$ implies that the magnitude of the influence of the median markup is highest in sectors with higher financial dependence. Consider for instance a sector with a level of financial dependence at the 90th percentile in column (4). For plants 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.

Robustness As a robustness check, appendix H provides 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 (38), (39), (40), (41). 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 strongly statistically significant.[42] 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).

Columns 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.

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

[41] Note that the coefficient on $MRPK_{irst-1} * FinDep_s$ is always positive, which is consistent with MRPK convergence being slower in more financially dependent sectors because of the stronger salience of financial constraints.

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

The heterogeneous effect is not generally statistically significant, but it is significant in columns 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.

Conclusion 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.

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**	0.327**	0.413**	0.305**				
	(0.00571)	(0.00563)	(0.00639)	(0.00772)				
$MRPK_{irst-1}$ (GR) * $Median_{rst-1}[\ln \mu_{irst-1}]$	-0.00340**	-0.0339**	-0.000861	0.00155				
	(0.00131)	(0.0139)	(0.00213)	(0.0139)				
$MRPK_{irst-1}$ (GR) * $Fin\ Dep_s$			0.00887	0.0382*				
			(0.00572)	(0.0154)				
$MRPK_{irst-1}$ (GR) * $Median_{rst-1}[\ln \mu_{irst-1}]$ * $Fin\ Dep_s$			-0.0124**	-0.0634*				
			(0.00439)	(0.0271)				
$MRPK_{irst-1}$ (VA)					0.296**	0.189**	0.279**	0.160**
					(0.00527)	(0.00508)	(0.00613)	(0.00717)
$MRPK_{irst-1}$ (VA) * $Median_{rst-1}[\ln \mu_{irst-1}]$					-0.0103**	-0.0306**	-0.00522	0.0000582
					(0.00195)	(0.0105)	(0.00306)	(0.0144)
$MRPK_{irst-1}$ (VA) * $Fin\ Dep_s$							0.0198**	0.0593**
							(0.00688)	(0.0139)
$MRPK_{irst-1}$ (VA) * $Median_{rst-1}[\ln \mu_{irst-1}]$ * $Fin\ Dep_s$							-0.0160**	-0.0229
							(0.00612)	(0.0252)
Influence of $Median_{rst-1}[\ln \mu_{irst-1}]$ on convergence speed:								
$\rho_1 * [90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$	-0.00641	-0.0639	-0.00162	0.00292	-0.0194	-0.0577	-0.00984	0.000109
$[\rho_1 + \rho_3 * Fin\ Dep_s(90\%ile)] *$ $(90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)])$			-0.0196	-0.0889			-0.0330	-0.0330
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	No	Yes	No	Yes	No	Yes	No
State-sector-year FE	No	Yes	No	Yes	No	Yes	No	Yes
Observations	238359	238359	196323	196323	196162	196162	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, $Median_{rst}[\ln \mu_{irst}]$, is demeaned within sectors. All specifications include a quadratic polynomial of firm 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 specifications (3,4,6,7), 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

Table 4: Speed of Convergence for Young Plants

	Plant-level Capital Growth $g(k_{irst})$											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
$Median_{rst}[\ln \mu_{irst-1}] * 1(age \leq 5)$	0.0191**			0.0234**			0.0110			0.0118		
	(0.00649)			(0.00547)			(0.0105)			(0.00806)		
$Median_{rst}[\ln \mu_{irst-1}] * 1(age < 10)$		0.00937			0.0130*			0.00775			0.00316	
		(0.00542)			(0.00511)			(0.00858)			(0.00735)	
$Median_{rst}[\ln \mu_{irst-1}] * [[\ln(\frac{1}{age_{irst}})]$			0.00704*			0.00768**			0.00371			0.00544
			(0.00285)			(0.00257)			(0.00445)			(0.00371)
$Median_{rst}[\ln \mu_{irst-1}] * 1(age \leq 5) * Fin\ Dep_s$							0.0396*			0.0346*		
							(0.0200)			(0.0173)		
$Median_{rst}[\ln \mu_{irst-1}] * 1(age < 10) * Fin\ Dep_s$								0.0197			0.0189	
								(0.0170)			(0.0153)	
$Median_{rst}[\ln \mu_{irst-1}] * [\ln(\frac{1}{age_{irst}})] * Fin\ Dep_s$									0.0187*			0.00775
									(0.00811)			(0.00707)
$1(age \leq 5)$	0.0631**			0.0343**			0.0628**			0.0297**		
	(0.00333)			(0.00322)			(0.00358)			(0.00346)		
$1(age < 10)$		0.0385**			-0.00423			0.0395**			-0.00625	
		(0.00271)			(0.00316)			(0.00292)			(0.00343)	
$\ln(\frac{1}{age_{irst}})$			0.0142**			0.0244**			0.0151**			0.0237**
			(0.00150)			(0.00242)			(0.00164)			(0.00269)
$Median_{rst}[\ln(\mu_{irst-1})]$				0.00228	0.00289	0.0261**				0.00497	0.00679	0.0225*
				(0.00309)	(0.00348)	(0.00646)				(0.00452)	(0.00499)	(0.00933)
$Median_{rst}[\ln(\mu_{irst-1})] * Fin\ Dep_s$										-0.00555	-0.00422	0.0138
										(0.00888)	(0.00926)	(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
$[\beta_2 + \beta_3 * Fin\ Dep_s(90\%ile)] *$ $[90\%ile[Median(\ln \mu)] - 10\%ile[Median(\ln \mu)]]$							0.0781	0.0431	0.0341	0.0723	0.0333	0.0215
State-sector-year FE	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No
Plant FE, Year FE	No	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, $Median_{rst}[\ln \mu_{irst}]$, 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, due to different median markups, 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 panel of Indian manufacturing plants. In that setting, the identifying assumption was that the state-sector level of competition is exogenous to the individual plant. While this analysis has the advantages of employing the full panel of plants, a potential limitation is that the underlying source of the variation in competition remains 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 mandated that only industrial undertakings below a certain investment ceiling (Rs. 10 million at historical cost in 1999) were allowed to produce certain product categories.[43] 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. A first argument for this exogeneity is given by Tewari and Wilde (2014), who document that there is considerable variation in the timing of dereservation within narrow product categories. As products within these narrow product categories arguably share the same demand and supply characteristics, this limits the scope for a structural explanation of the timing of dereservation. Moreover, Tewari and Wilde (2014) show that dereservation is uncorrelated with observable pre-policy characteristics of an industry. A more detailed description of the implementation of dereservation is provided by García-Santana and Pijoan-Mas (2014); Martin et al. (2014) and Tewari and Wilde (2014).

Dereservation has two distinct structural effects on incumbent plants. First, the direct effect of the removal of the investment ceiling is that incumbent establishments 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 plant is now allowed to produce the previously reserved product. As a result, there is substantial scope for entry into the production of dereserved products. In case the pro-competitive shock is the dominant effect on a certain subset of incumbents, I can utilize the dereservation reform as an exogenous increase in the degree of competition for this subset of plants.

[43] At the time of reservation, an exception was made for large industrial undertakings already producing the product. These undertakings were allowed to continue production, but with output capped at existing levels.

6.2 Empirical analysis

6.2.1 Data

Data on the dereservation reform has 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 plants 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 in year t if that plant's main product has been deserved during that financial year.[44]

6.2.2 Econometric 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 profitability. In order for the dereservation reform to be relevant for the analysis in this paper, the presence of the indirect pro-competitive effect is required. To examine whether this is the case, I run the following event-study on dereservation, implemented at time $t = 0$.

$$y_{irst} = \alpha_{rs} + \gamma_t + \sum_{\tau=-4}^{4} \beta_\tau 1(t = \tau) + \varepsilon_{irst} \tag{42}$$

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

Capital convergence After checking if the dereservation indeed has a pro-competitive impact, I examine its impact on 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 (36) in the dereservation setting is:

$$\begin{aligned} MRPK_{irst} = \alpha_{irs} + \beta_1 1(Dereserved_{irst-1}) + \rho_0 MRPK_{irst-1} \\ + \rho_1 MRPK_{irst-1} * 1(Dereserved_{irst-1}) + \beta_2 X_{irst} + \varepsilon_{irst} \end{aligned} \tag{43}$$

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 $\rho_1 > 0$.

In addition, I examine the effect of dereservation on capital growth for young plants. To this end, I implement the analogue of specification (38), now in the dereservation setting:

$$\begin{aligned} g(k_{irst}) = \alpha_{irs} + \beta_1 (Dereserved_{irst-1}) + \beta_2 young_{irst} \\ + \beta_3 1(Dereserved_{irst-1}) * young_{irst} + \beta_4 X_{irst} + \varepsilon_{irst} \end{aligned} \tag{44}$$

[44] Since the implementation of dereservation starts in 1997, I use the NIC 1998 definition of sectors in the empirical analysis of dereservation.

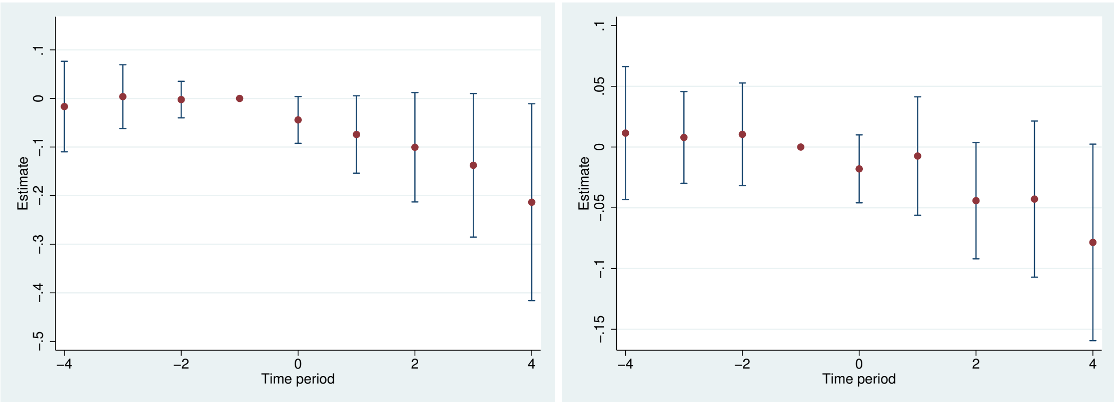
The prediction is now that $\beta_3 < 0$, in case the increase in competition due to dereservation leads to slower capital growth for young firms. The next subsection discusses the estimation results for the above specifications.

6.2.3 Results

Event Study: Pro-competitive shock First, I implement specification (42) to examine the pro-competitive impact of dereservation on incumbent plants and Figure 2 shows the results.

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

(a) Plant-level Markup (b) Capital Growth



The figure displays the coefficients and 95% confidence intervals of an event-study regression on dereservation. Panels (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 $\beta_{-1} = 0$, and standard errors are clustered at the plant-level.

Panel (a) indicates that plant-level markups fall after dereservation, which is consistent with a substantial pro-competitive effect of dereservation. In addition, panel (b) displays that capital growth of incumbent plants 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 G, I further examine if there is heterogeneity in the pro-competitive impact of dereservation. There, I find that for urban plants, which account for 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, one would expect a stronger impact of dereservation on capital convergence for urban plants.[45] Below I examine if this expectation is confirmed by the

[45]Note 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.

data.

Capital convergence Table 5 presents the impact of dereservation on MRPK convergence. 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, columns (3,6) indicate that dereservation especially slows down MRPK convergence for urban plants. This would be consistent with the findings from appendix G, which show that the pro-competitive impact of dereservation is particularly pronounced for urban incumbents.

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	-0.0396	-0.0381	0.127*	0.0679	0.0607
	(0.0409)	(0.0467)	(0.0485)	(0.0611)	(0.0628)	(0.0651)
$1(Dereserved_{irst-1}) * 1(urban_{irs})$			0.0310			0.0221
			(0.0259)			(0.0311)
$MRPK_{irst-1}(GR)$	0.806**	0.497**	0.519**			
	(0.00873)	(0.0157)	(0.0160)			
$MRPK_{irst-1}(GR) * 1(Dereserved_{irst-1})$	0.00627	-0.0130	-0.0226			
	(0.0137)	(0.0151)	(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**	0.347**	0.350**
				(0.0111)	(0.0142)	(0.0142)
$MRPK_{irst-1}(VA) * 1(Dereserved_{irst-1})$				0.0353*	0.0213	0.00950
				(0.0154)	(0.0154)	(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 nega-

Table 6: Speed of Convergence for Young Plants after Dereservation

	Plant-level Capital Growth $g(k_{irst})$					
	(1)	(2)	(3)	(4)	(5)	(6)
$1(Dereserved_{irst})$	-0.00916	0.0218*	-0.00620	0.0269**	-0.101**	-0.0779**
	(0.0167)	(0.00871)	(0.0176)	(0.00853)	(0.0261)	(0.0235)
$1(Dereserved_{irst}) * 1(age_{irst} \leq 5)$	-0.0705**	-0.121**				
	(0.0209)	(0.0212)				
$1(Dereserved_{irst}) * 1(age_{irst} < 10)$			-0.0429**	-0.0741**		
			(0.0123)	(0.0121)		
$1(Dereserved_{irst}) * [\ln(\frac{1}{age_{irst}})]$					-0.0316**	-0.0270**
					(0.00881)	(0.00787)
$1(age_{irst} \leq 5)$	0.0683**	0.0576**				
	(0.0158)	(0.0121)				
$1(age_{irst} < 10)$			0.0389**	0.0365**		
			(0.0117)	(0.00834)		
$\ln(\frac{1}{age_{irst}})$					0.0204*	0.0277**
					(0.00788)	(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.

tive effects on capital convergence for incumbents, in line with the model's prediction that higher competition leads to slower convergence. A discussion of the broader (welfare) effects of dereservation can be found in García-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 well known in the misallocation literature, the negative impact of competition in a setting with financial constraints was previously under examined.

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

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

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

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

Therefore:

$$Q_t = TFP_t K_t^{\alpha} L^{1-\alpha} \tag{45}$$

where

$$TFP_t \equiv M \left[E_{it} \left(a_{it}^{\eta} \left(\frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}}{\sum_{i=1}^{M} \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}}} \right)^{\alpha\eta} \left(\frac{\frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^{M} \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}}{\sum_{i=1}^{M} \frac{\left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{\alpha\eta}} \right)^{\frac{1}{1-\eta}}}{\left[\sum_{i=1}^{M} \left(\frac{a_{it}^{\eta}}{\mu_{it}\omega_{it}^{1+\alpha\eta-\eta}} \right)^{\frac{1}{1-\eta}} \right]^{\frac{\alpha\eta}{1+\alpha\eta-\eta}}}} \right)^{\eta-\alpha\eta} \right) \right]^{1/\eta} \tag{46}$$

A.2 Labor market equilibrium

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

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

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

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

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

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 Proof for Proposition 1

Proposition 1 has three components and the following appendix sections provide the proof for each of the three components. It will be convenient to first focus on the third component, namely the relation between capital wedges and competition.

B.1 Overview of the proof

First, I demonstrate what the sufficient conditions are for the proposition's statement for capital wedges, namely that $\forall \tau : \frac{d\omega_\tau}{dM} \geq 0$ and $(\Phi_\tau > 0) \implies \frac{d\omega_\tau}{dM}$. To demonstrate this, I start from equation (26), which for convenience is reiterated here:

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

Therefore:

$$\begin{aligned} \frac{d\omega_\tau}{dM} = &- \frac{1-\eta}{1+\alpha\eta-\eta} G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}-1} \frac{dG_\tau}{dM} \left[\frac{a_H^\eta}{a_L^\eta} \frac{\mu_L}{\mu_\tau} \right]^{\frac{1}{1+\alpha\eta-\eta}} r_L \\ &+ \frac{1}{1+\alpha\eta-\eta} \left(\frac{\mu_L}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}-1} \frac{d(\frac{\mu_L}{\mu_\tau})}{dM} G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^\eta}{a_L^\eta} \right]^{\frac{1}{1+\alpha\eta-\eta}} r_L \\ &+ G_\tau^{-\frac{1-\eta}{1+\alpha\eta-\eta}} \left[\frac{a_H^\eta}{a_L^\eta} \frac{\mu_L}{\mu_\tau} \right]^{\frac{1}{1+\alpha\eta-\eta}} \frac{dr_L}{dM} \end{aligned}$$

In this preliminary version of the paper, I assume that $\frac{dr_L}{dM} = 0$. A sufficient condition for $\frac{d\omega_\tau}{dM} \geq 0$ and $(\Phi_\tau > 0) \implies \frac{d\omega_\tau}{dM}$ to hold, is then the following two conditions hold:

- $\forall \tau > 0 : ((\frac{dG_\tau}{dM} \leq 0) \wedge (\Phi_\tau > 0)) \implies \frac{dG_\tau}{dM} < 0$
- $\forall \tau > 0 : \frac{d(\frac{\mu_L}{\mu_\tau})}{dM} > 0$

Here is then the outline for the proof.

- First, I will derive an expression for capital growth, and show how it depends on μ_τ, μ_L.
- Then, for any $M' > M$, I will consider two cases: either $\mu'_L \geq \mu_L$ or $\mu'_L < \mu_L$. I demonstrate that $\mu'_L \geq \mu_L$ results in a contradiction and therefore $\mu'_L < \mu_L$ holds. Intuitively, $\mu'_L \geq \mu_L$ leads to a contradiction, because it implies a higher market share for a_L-type firms, while at the same time increasing G_τ and thereby inducing higher market shares for a_H-type firms as well. Increasing market shares for both a_L, a_H-type firms then contradicts with the average market share decreasing with M.
- I then show that $\mu'_L < \mu_L$ implies that
  - $\forall \tau > 0 : G'_\tau \leq G_\tau \wedge ((\Phi_\tau > 0) \implies G'_\tau < G_\tau)$
  - $\forall \tau > 0 : \mu'_\tau \leq \mu_\tau$
  - $\forall \tau > 0 : \frac{\mu'_L}{\mu'_\tau} > \frac{\mu_L}{\mu_\tau}$

  which concludes the proof. This pattern for markups and capital growth is intuitive: increased M lowers markups for all types of firms, which at the same time reduces capital growth for financially constrained firms. The theoretical challenge lies in demonstrating that this is the only possible pattern for markups and capital growth.

B.2 Expression for capital growth

I consider capital growth for all firms with $\tau \geq 0$. This type of firms are only heteregenous across different bins τ, and are perfectly homogeneous within a bin τ. At the same time, as explained in the paper, capital k_τ for these firms is predetermined, and their productivity a_τ is exogenous: $a_0 = a_L, \forall \tau > 0 : a_\tau = a_H$.

Financially constrained firms, i.e. firms with $\Phi_\tau > 0$, invest all their retained earnings into capital investment. Therefore, for a financially constrained firm in bin τ, capital growth $g(k_\tau) = \frac{(\mu_\tau - \frac{AC_\tau}{MC_\tau}) y_\tau MC_\tau}{k_\tau} - \delta$, where AC_τ is average cost and MC_τ is marginal cost.

The firm's total costs, for any quantity $\bar{y}_\tau$ are $TC(\bar{y}_\tau) = \frac{w}{P} L(\bar{y}_\tau)$. Here, since a_τ, and k_τ are exogenous and predetermined, respectively, setting $\bar{y}_\tau$ directly implies setting $\bar{l}_\tau$ since $\bar{y}_\tau = a_H k_\tau^\alpha \bar{l}_\tau^{1-\alpha}$. This means that $L(\bar{y}_\tau) = \left(\frac{\bar{y}_\tau}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}$, such that $TC(\bar{y}_\tau) = \frac{w}{P}\left(\frac{\bar{y}_\tau}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}$

Therefore:

$$MC_\tau(\bar{y}_\tau) = \frac{\partial TC(\bar{y}_\tau)}{\partial \bar{y}_\tau} = \frac{w}{(1-\alpha)P}\left(\frac{\bar{y}_\tau^\alpha}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}$$

$$AC_\tau(\bar{y}_\tau) = \frac{w}{P}\frac{1}{\bar{y}_\tau}\left(\frac{\bar{y}_\tau}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}} = \frac{w}{P}\left(\frac{\bar{y}_\tau^\alpha}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}$$

Which implies that

$$\frac{AC_\tau(\bar{y}_\tau)}{MC_\tau(\bar{y}_\tau)} = (1-\alpha)$$

Capital growth expression Start with derivation of profits, where $\bar{\mu}_\tau$ is determined by choosing $\bar{y}_\tau$ and setting the price given the demand function.

$$\pi_\tau = \left(\bar{\mu}_\tau - \frac{AC_\tau}{MC_\tau}\right)\bar{y}_\tau * MC_\tau = \left(\bar{\mu}_\tau - (1-\alpha)\right)\frac{w}{(1-\alpha)P}\left(\frac{\bar{y}_\tau^\alpha}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}\bar{y}_\tau$$

$$\pi_\tau = \left(\bar{\mu}_\tau - (1-\alpha)\right)\frac{w}{P(1-\alpha)}\left(\frac{\bar{y}_\tau}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}}$$

Hence,

$$\frac{\pi_\tau}{k_\tau} = \left(\bar{\mu}_\tau - (1-\alpha)\right)\frac{w}{P(1-\alpha)k_\tau}\left(\frac{\bar{y}_\tau}{a_H k_\tau^\alpha}\right)^{\frac{1}{1-\alpha}} = \left[\bar{\mu}_\tau - (1-\alpha)\right]\frac{w}{P(1-\alpha)}\left(\frac{\bar{y}_\tau}{a_H k_\tau}\right)^{\frac{1}{1-\alpha}}$$

and since $\bar{y}_\tau = a_\tau k_\tau^\alpha \bar{l}_\tau^{1-\alpha}$

$$\frac{\pi_\tau}{k_\tau} = \left(\bar{\mu}_\tau - (1-\alpha)\right)\frac{w}{P(1-\alpha)}\left(\frac{a_\tau \bar{l}_\tau^{1-\alpha}}{a_\tau k_\tau^{1-\alpha}}\right)^{\frac{1}{1-\alpha}} = \left[\bar{\mu}_\tau - (1-\alpha)\right]\frac{w}{P(1-\alpha)}\frac{\bar{l}_\tau}{k_\tau}$$

Since all profits are invested in capital growth, we have for $\Phi_\tau > 0$:

$$\frac{k_{\tau+1}(\bar{l}_\tau) - k_\tau}{k_\tau} = \frac{\pi_\tau}{k_\tau} - \delta = \left[\bar{\mu}_\tau - (1-\alpha)\right]\frac{w}{P(1-\alpha)}\frac{\bar{l}_\tau}{k_\tau} - \delta$$

Given the expression for $\frac{\pi_\tau}{k_\tau}$, we need to determine $\mu_\tau, \frac{\bar{l}_\tau}{k_\tau}$. These variables are outcomes of the optimization problem, where optimal labor l_τ is from equation (18) in the paper, while for capital $k_\tau = G_\tau k_L$. Finally, the markup is also optimally determined as μ_τ, defined in equation (24).

Remember:

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

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

therefore

$$\frac{l_\tau^*}{G_\tau k_L^*} = \frac{P(1-\alpha)}{G_\tau w} \left(\frac{a_\tau}{a_L} \right)^{\frac{\eta}{1+\alpha\eta-\eta}} \frac{r_L}{\alpha} \left(\frac{\mu_L}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}}$$

which implies that for $g(k)_\tau \equiv \frac{k_{\tau+1}(l_\tau)-k_\tau}{k_\tau}$

$$\forall \tau \text{ where } \Phi_\tau > 0 : g(k)_\tau = \frac{1}{G_\tau} \left[\mu_\tau - (1-\alpha) \right] \left(\frac{a_\tau}{a_L} \right)^{\frac{\eta}{1+\alpha\eta-\eta}} \frac{r_L}{\alpha} \left(\frac{\mu_L}{\mu_\tau} \right)^{\frac{1}{1+\alpha\eta-\eta}} - \delta$$

or

$$\forall \tau \text{ with } \Phi_\tau > 0 : \ln(G_\tau(g(k)_\tau + \delta)) = \ln\left[\mu_\tau - (1-\alpha) \right] + \ln\left(\frac{a_\tau}{a_L} \right)^{\frac{\eta}{1+\alpha\eta-\eta}} \frac{r_L}{\alpha} - \frac{\ln\left(\frac{\mu_\tau}{\mu_L}\right)}{1+\alpha\eta-\eta} \quad (47)$$

Derivative with respect to M Assuming r_L is constant, and only considering τ where $\Phi_\tau > 0$ we find that

$$\frac{\partial \ln(G_\tau(g(k)_\tau + \delta))}{\partial M} = \frac{\frac{\partial \mu_\tau}{\partial M}}{\left[\mu_\tau - (1-\alpha) \right]} - \frac{1}{1+\alpha\eta-\eta} \frac{\mu_L}{\mu_\tau} \left[\frac{\partial \mu_\tau}{\partial M} \frac{1}{\mu_L} - \frac{\mu_\tau}{\mu_L^2} \frac{\partial \mu_L}{\partial M} \right]$$

Rearranging:

$$\frac{\partial \ln(G_\tau(g(k)_\tau + \delta))}{\partial M} = \frac{\partial \mu_\tau}{\partial M} \left(\frac{1}{\left[\mu_\tau - (1-\alpha) \right]} - \frac{1}{1+\alpha\eta-\eta} \frac{1}{\mu_\tau} \left[1 - \frac{\mu_\tau}{\mu_L} \frac{\frac{\partial \mu_L}{\partial M}}{\frac{\partial \mu_\tau}{\partial M}} \right] \right) \quad (48)$$

Note that a sufficient condition for $sign(\frac{\partial \ln(G_\tau(g(k)_\tau+\delta))}{\partial M}) = sign(\frac{\partial \mu_\tau}{\partial M})$, is that $sign(\frac{\partial \mu_\tau}{\partial M}) = sign(\frac{\partial \mu_L}{\partial M})$. This is because

$$\left(\frac{1}{\left[\mu_\tau - (1-\alpha) \right]} - \frac{1}{1+\alpha\eta-\eta} \frac{1}{\mu_\tau} \left[1 - \frac{\mu_\tau}{\mu_L} \frac{\frac{\partial \mu_L}{\partial M}}{\frac{\partial \mu_\tau}{\partial M}} \right] > 0 \right) \iff \left(1 > \frac{\left[1 - \frac{(1-\alpha)}{\mu_\tau} \right]}{1-\eta(1-\alpha)} \left[1 - \frac{\mu_\tau}{\mu_L} \frac{\frac{\partial \mu_L}{\partial M}}{\frac{\partial \mu_\tau}{\partial M}} \right] \right)$$

and $\left(sign(\frac{\partial \mu_\tau}{\partial M}) = sign(\frac{\partial \mu_L}{\partial M}) \right) \implies \left(0 > -\frac{\mu_\tau}{\mu_L} \frac{\frac{\partial \mu_L}{\partial M}}{\frac{\partial \mu_\tau}{\partial M}} \right)$. Hence, a key step in the remainder of the proof will be demonstrating that $\left(sign(\frac{\partial \mu_\tau}{\partial M}) = sign(\frac{\partial \mu_L}{\partial M}) \right)$ holds globally.

B.3 Impact of competition on distribution of markups and capital growth

Given equation (48), I will now examine the level of markups and capital growth, across any two different levels for the number of firms in the economy, namely $M' > M$, where I denote with a prime the values under M'. Specifically, I will examine two cases. First, $\mu'_L \geq \mu_L$ and second $\mu'_L < \mu_L$. The first case will result in a contradiction, so its opposite - the second case - must be true. The analysis in the second case will then characterize the path of markups and capital growth across different M. For the analysis, it will be useful to define $\mathcal{G}_\tau \equiv \frac{y_\tau^\eta}{y_L^\eta}$.

B.3.1 Case 1: $\mu'_L \geq \mu_L$

This case will result in a contradiction, and therefore its opposite must be true. The proof proceeds by induction.

Step 1 Consider $\tau = 0$, where productivity is a_L and $\mu_0 = \mu_L$, but the firm learns it will have productivity a_H in $\tau = 1$. In this period, if $\Phi_0 > 0$, capital growth is

$$g(k)_0 = [\mu_L - (1-\alpha)]\frac{r_L}{\alpha} \tag{49}$$

Therefore $g(k)'_0 \geq g(k)_0$ since $\mu'_L \geq \mu_L$ and the other variables are constant.

Inductive step For the inductive step, I show first that for any period $\tau > 0$ with $G'_\tau \geq G_\tau$:

$$((G'_\tau \geq G_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau \geq \mu_\tau)$$

To show this, notice that $(\mathcal{G}'_\tau \geq \mathcal{G}_\tau)/(\mathcal{G}'_\tau < \mathcal{G}_\tau)$, and in both cases, I show that $(\mu'_\tau \geq \mu_\tau)$ holds

- Case (i): $((\mathcal{G}'_\tau \geq \mathcal{G}_\tau) \wedge (G'_\tau \geq G_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau \geq \mu_\tau)$. This follows from $((\mathcal{G}'_\tau \geq \mathcal{G}_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau \geq \mu_\tau)$.
  - From equations (9), (10), it is clear that μ_L is monotonically increasing in $\frac{y_L^\eta}{\sum y_{it}^\eta}$. Therefore, $(\mu'_L \geq \mu_L) \iff \left(\frac{y_L'^\eta}{\sum y_{it}'^\eta} \geq \frac{y_L^\eta}{\sum y_{it}^\eta}\right)$. Then, $(\mathcal{G}'_\tau \geq \mathcal{G}_\tau) \wedge \left(\frac{y_L'^\eta}{\sum y_{it}'^\eta} \geq \frac{y_L^\eta}{\sum y_{it}^\eta}\right) \implies \left(\frac{\mathcal{G}'_\tau y_L'^\eta}{\sum y_{it}'^\eta} \geq \frac{\mathcal{G}_\tau y_L^\eta}{\sum y_{it}^\eta} \wedge \mu'_\tau \geq \mu_\tau\right)$
- Case (ii): $((\mathcal{G}'_\tau < \mathcal{G}_\tau) \wedge (G'_\tau \geq G_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau \geq \mu_\tau)$.
  - Note that $\mathcal{G}_\tau \equiv \frac{y_\tau^\eta}{y_L^\eta} = \frac{(a_H G_\tau^\alpha l_\tau^{1-\alpha})^\eta}{(a_L l_L^{1-\alpha})^\eta}$. Therefore $(\mathcal{G}'_\tau < \mathcal{G}_\tau) \implies \left((G'_\tau < G_\tau) \vee (\frac{l'_\tau}{l'_L} < \frac{l_\tau}{l_L})\right)$ such that $\left((G'_\tau \geq G_\tau) \wedge (\frac{l'_\tau}{l'_L} \geq \frac{l_\tau}{l_L})\right) \implies (\mathcal{G}'_\tau \geq \mathcal{G}_\tau)$
  - Note that $\frac{l_\tau}{l_L} = \left(\frac{\mu_L}{\mu_\tau}\frac{a_H}{a_L}G_\tau^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}}$. Therefore, $\left((\frac{l'_\tau}{l'_L} < \frac{l_\tau}{l_L}) \wedge (G'_\tau \geq G_\tau)\right) \implies \frac{\mu'_L}{\mu'_\tau} < \frac{\mu_L}{\mu_\tau}$
  - In this case, $(\mathcal{G}'_\tau < \mathcal{G}_\tau) \wedge (G'_\tau \geq G_\tau) \implies \left(\frac{l'_\tau}{l'_L} < \frac{l_\tau}{l_L}\right)$. However, $\left(\frac{l'_\tau}{l'_L} < \frac{l_\tau}{l_L}\right) \implies \frac{\mu'_L}{\mu'_\tau} < \frac{\mu_L}{\mu_\tau}$. Therefore, $((\mathcal{G}'_\tau < \mathcal{G}_\tau) \wedge (G'_\tau \geq G_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau > \mu_\tau)$.
- Therefore, $((G'_\tau \geq G_\tau) \wedge (\mu'_L \geq \mu_L)) \implies (\mu'_\tau \geq \mu_\tau)$,

Given equation (48), $((\Phi_\tau > 0) \wedge (\mu'_\tau > \mu_\tau) \wedge (\mu'_L \geq \mu_L) \wedge (G'_\tau \geq G_\tau)) \implies G'_{\tau+1} \geq G_{\tau+1}$. This completes the inductive step.

Final step In case $\Phi_0 > 0$, then $g(k)'_0 \geq g(k)_0$. Hence, $(G'_1 \geq G_1) \implies (\mu'_1 \geq \mu_1)$. Therefore, this proof by induction implies that $(\mu'_L \geq \mu_L) \implies (\forall \tau > 0 \land \Phi_\tau > 0 : (\mu'_\tau \geq \mu_\tau)$. At the same time, $((M' > M) \land (\mu'_L > \mu_L)) \implies \exists \tau > 0 : (\mu'_\tau < \mu_\tau)$, which will yield a contradiction.

- To see that $((M' > M) \land (\mu'_L > \mu_L)) \implies \exists \tau : (\mu'_\tau < \mu_\tau)$, note that equations (9) and (10) for the markup and the demand elasticity entail that for any firm i: $(\mu'_{it} \geq \mu_{it}) \iff \left(\frac{y'^\eta_{it}}{\sum_i y'^\eta_{it}} \geq \frac{y^\eta_{it}}{\sum_i y^\eta_{it}}\right)$. Suppose for $M' > M$, we have $((\mu'_L \geq \mu_L) \land (\forall \tau > 0 : \mu'_\tau \geq \mu_\tau)) \implies \left((\frac{y'^\eta_L}{\sum_i y'^\eta_{it}} \geq \frac{y^\eta_L}{\sum_i y^\eta_{it}}) \land (\frac{y'^\eta_\tau}{\sum_i y'^\eta_{it}} \geq \frac{y^\eta_\tau}{\sum_i y^\eta_{it}})\right)$. Then,

$$\left((\frac{y'^\eta_L}{\sum_i y'^\eta_{it}} \geq \frac{y^\eta_L}{\sum_i y^\eta_{it}}) \land (\frac{y'^\eta_\tau}{\sum_i y'^\eta_{it}} \geq \frac{y^\eta_\tau}{\sum_i y^\eta_{it}})\right)$$
$$\implies \left(\frac{M'[Prob(a_{it} = a_L)\frac{y'^\eta_L}{\sum_i y'^\eta_{it}} + \sum_{\tau=1}^{\infty} Prob((a_{it} = a_H)\&(t = \tau))\frac{y'^\eta_\tau}{\sum_i y'^\eta_{it}}]}{M[Prob(a_{it} = a_L)\frac{y^\eta_L}{\sum_i y^\eta_{it}} + \sum_{\tau=1}^{\infty} Prob((a_{it} = a_H)\&(t = \tau))\frac{y^\eta_\tau}{\sum_i y^\eta_{it}}]} > 1\right)$$

  Which is a contradiction since both the denominator and the numerator in the ratio after the implication are equal to 1. This is because $\sum_i y^\eta_{it} = M[Prob(a_{it} = a_L)y^\eta_L + \sum_{\tau=1}^{\infty} Prob((a_{it} = a_H)\&(t = \tau))y^\eta_\tau]$. Since $M' > M \land ((\mu'_L \geq \mu_L) \land (\forall \tau > 0 : \mu'_\tau \geq \mu_\tau))$ entails a contradiction, $\exists \tau > 0 : (\mu'_\tau < \mu_\tau)$, under the continued assumption that $\mu'_L \geq \mu_L$.

- $(\exists \tau > 0 : (\mu'_\tau < \mu_\tau)) \implies ((\exists \tau > 0 : \Phi_\tau > 0 \land (\mu'_\tau < \mu_\tau)) \lor (\exists \tau > 0 : \Phi_\tau = 0 \land (\mu'_\tau < \mu_\tau)))$, but both cases result in a contradiction.
  - Case a: $(\exists \tau > 0 : \Phi_\tau > 0 \land (\mu'_\tau < \mu_\tau))$. This does not hold, since the proof by induction implies $(\mu'_L \geq \mu_L) \implies (\forall \tau > 0 \land \Phi_\tau > 0 : (\mu'_\tau \geq \mu_\tau)$.
  - Case b is equivalent to $(\mu'_H < \mu_H)$. We know that $(\mu'_L > \mu_L) \land (\mu'_H < \mu_H) \implies (\mathcal{G}'_H < \mathcal{G}_H)$, where $\mathcal{G}_H = \frac{(a_H G^\alpha_H l^{1-\alpha}_H)^\eta}{a_L l^{1-\alpha}_L)^\eta}$. Hence, $(\mathcal{G}'_H < \mathcal{G}_H) \implies \left((G'_H < G_H) \lor (\frac{l'_H}{l'_L} < \frac{l_H}{l_L})\right)$. There are then again two cases, both of which result in a contradiction:
    * Case b1: since $G_H = (\frac{a_H}{a_L}\frac{\mu_L}{\mu_H})^{1/(1-\eta)}$, $(G'_H < G_H) \implies (\frac{\mu'_L}{\mu'_H} < \frac{\mu_L}{\mu_H})$. However, $(\mu'_L > \mu) \land (\frac{\mu'_L}{\mu'_H} < \frac{\mu_L}{\mu_H}) \implies (\mu'_H > \mu_H)$, which contradicts the supposition that $(\mu'_H < \mu_H)$
    * Case b2: Since $\frac{l_\tau}{l_L} = \left(\frac{\mu_L}{\mu_\tau}\frac{a_H}{a_L}G^{\alpha\eta}_\tau\right)^{\frac{1}{1+\alpha\eta-\eta}}$, $(\frac{l'_H}{l'_L} < \frac{l_H}{l_L}) \land (G'_H \geq G_H) \implies (\frac{\mu'_L}{\mu'_H} < \frac{\mu_L}{\mu_H})$, which again results in a contradiction

Since the supposition that $\mu'_L \geq \mu_L$ entails a contradiction, its opposite must be true: $\mu'_L < \mu_L$

B.3.2 Case 2: $\mu'_L < \mu_L$

Step 1 Consider $\tau = 0$, from equation (49), it is clear that

$$((\mu'_L < \mu_L) \land (\Phi_0 > 0)) \implies \left((g(k)'_0 < g(k)_0) \land (G'_1 < G_1)\right)$$

Inductive step For the inductive step, I show first that for any period $\tau > 0$:

$$(G'_\tau < G_\tau) \land (\mu'_L < \mu_L) \implies (\mu'_\tau < \mu_\tau)$$

To prove that $(G'_\tau < G_\tau) \land (\mu'_L < \mu_L) \implies (\mu'_\tau < \mu_\tau)$, consider two cases:

- Case (i): $(G'_\tau < G_\tau) \wedge (\mu'_L < \mu_L) \wedge (\mathcal{G}'_\tau \leq \mathcal{G}_\tau) \implies (\mu'_\tau < \mu_\tau)$.
- Case (ii): $(G'_\tau < G_\tau) \wedge (\mu'_L < \mu_L) \wedge (\mathcal{G}'_\tau > \mathcal{G}_\tau) \implies (\mu'_\tau < \mu_\tau)$. This is because given $\mathcal{G}_\tau = \frac{(a_H G_\tau l_\tau)^\eta}{(a_L l_L)^\eta}$ and $\frac{l_\tau}{l_L} = \left(\frac{\mu_L}{\mu_\tau}\frac{a_H}{a_L}G_\tau^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}}$; $((G'_\tau < G_\tau) \wedge (\mathcal{G}'_\tau > \mathcal{G}_\tau)) \implies (\frac{l'_1}{l'_L} > \frac{l_1}{l_L})$ and $\left((\mu'_L < \mu_L) \wedge (\frac{l'_1}{l'_L} > \frac{l_1}{l_L}) \wedge (G'_\tau < G_\tau)\right) \implies \left((\frac{\mu'_L}{\mu'_\tau} > \frac{\mu_L}{\mu_\tau}) \iff (1 > \frac{\mu'_L}{\mu_L} > \frac{\mu'_\tau}{\mu_\tau})\right)$
- Therefore, $(G'_\tau < G_\tau) \wedge (\mu'_L < \mu_L) \implies (\mu'_\tau < \mu_\tau)$

Given equation (48), $((\Phi_\tau > 0) \wedge (\mu'_\tau < \mu_\tau) \wedge (\mu'_L < \mu_L) \wedge (G'_\tau < G_\tau)) \implies G'_{\tau+1} < G_{\tau+1}$. This completes the inductive step, which applies for any $\tau > 0$ with $\Phi_\tau > 0$.

Final step We know that when $\Phi_0 > 0$, $g(k)'_0 < g(k)_0$. Hence, $\Phi_0 > 0 \implies [(G'_1 < G_1) \implies (\mu'_1 < \mu_1)]$. Therefore, this proof by induction implies that

$$(\mu'_L < \mu_L) \implies \left[(\Phi_\tau > 0) \implies ((\mu'_\tau < \mu_\tau) \wedge (G'_\tau < G_\tau))\right]$$

Result for μ_H, G_H How do μ_H, G_H evolve with M? There are two cases: $\mathcal{G}'_H \leq \mathcal{G}_H$ or $\mathcal{G}'_H > \mathcal{G}_H$.

- Case a: $(\mathcal{G}'_H \leq \mathcal{G}_H) \implies (\mu'_H < \mu_H)$. Why? We know that $\mu'_L < \mu_L \iff (\frac{y_L'^\eta}{\sum_i y_{it}'^\eta} < \frac{y_L^\eta}{\sum_i y_{it}^\eta})$. Hence, $((\mu'_L < \mu_L) \wedge (\mathcal{G}'_H \leq \mathcal{G}_H)) \implies \left((\mathcal{G}'_H \frac{y_L'^\eta}{\sum_i y_{it}'^\eta} < \frac{\mathcal{G}_H y_L^\eta}{\sum_i y_{it}^\eta}) \iff (\mu'_H < \mu_H)\right)$
- Case b: $(\mathcal{G}'_H > \mathcal{G}_H)$.
  - Note that $\mathcal{G}_\tau \equiv \frac{y_H^\eta}{y_L^\eta} = \frac{(a_H G_\tau l_H)^\eta}{(a_L l_L^{1-\alpha})^\eta}$. Hence, $(\mathcal{G}'_H > \mathcal{G}_H) \iff (\frac{G_H'^\alpha l_H'^{1-\alpha}}{l'_L} < \frac{G_H^\alpha l_H^{1-\alpha}}{l_L})$. Therefore $(\mathcal{G}'_H > \mathcal{G}_H) \implies \left((G'_H > G_H) \vee (\frac{l'_H}{l'_L} > \frac{l_H}{l_L})\right)$. There are then again two cases
  - Case b1: suppose $(G'_H > G_H)$. Since $G_H = (\frac{a_H}{a_L}\frac{\mu_L}{\mu_H})^{1/(1-\eta)}$, $(G'_H > G_H) \implies \left((\frac{\mu'_L}{\mu'_H} > \frac{\mu_L}{\mu_H}) \iff (\frac{\mu'_L}{\mu_L} > \frac{\mu'_H}{\mu_H})\right)$. Therefore, $(G'_H > G_H) \wedge (\mu'_L < \mu_L) \implies$
  - Case b2: suppose $(\frac{l'_H}{l'_L} > \frac{l_H}{l_L}) \wedge (G'_H \leq G_H)$. Note that $\frac{l_H}{l_L} = \left(\frac{\mu_L}{\mu_H}\frac{a_H}{a_L}G_H^{\alpha\eta}\right)^{\frac{1}{1+\alpha\eta-\eta}}$. Therefore, $\left((\frac{l'_H}{l'_L} > \frac{l_H}{l_L}) \wedge (G'_H \leq G_H)\right) \implies (\frac{\mu'_L}{\mu'_H} > \frac{\mu_L}{\mu_H} \iff \frac{\mu'_L}{\mu_L} > \frac{\mu'_H}{\mu_H})$. Since $1 > \frac{\mu'_L}{\mu_L}$, we find that $(\frac{l'_H}{l'_L} > \frac{l_H}{l_L}) \wedge (G'_H \leq G_H) \implies (\mu'_H < \mu_H)$.
  - Therefore, we find that $(\mu'_H < \mu_H)$ and hence

$$(\mu'_L < \mu_L) \implies [\forall \tau > 0 : ((\mu'_\tau < \mu_\tau))]$$

B.4 Relative markups and M

From the previous subsection, I know that

$$(\mu'_L < \mu_L) \wedge (\forall \tau > 0 : \mu'_\tau < \mu_\tau) \wedge \left((\Phi_\tau > 0) \implies (G'_\tau < G_\tau)\right)$$

As is already clear from the inductive step in subsection B.3.2, there are two cases: either $\mathcal{G}'_\tau \leq \mathcal{G}_\tau$ or $\mathcal{G}'_\tau > \mathcal{G}_\tau$. I now demonstrate that in both cases, $\frac{\mu'_L}{\mu'_\tau} > \frac{\mu_L}{\mu_\tau}$.

- In case $\mathcal{G}'_\tau > \mathcal{G}_\tau$, then case (ii) in subsection B.3.2 demonstrates that

$$((G'_\tau < G_\tau) \wedge (\mu'_L < \mu_L) \wedge (\mathcal{G}'_\tau > \mathcal{G}_\tau)) \implies \left(\frac{\mu'_L}{\mu'_\tau} > \frac{\mu_L}{\mu_\tau}\right)$$

- In case $\mathcal{G}'_\tau \leq \mathcal{G}_\tau$, then start from the expression for relative markups, derived from equation (9):

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

First, define $\frac{y_\tau^\eta}{y_L^\eta} \equiv \mathcal{G}_\tau$, such that:

$$\frac{\mu_L}{\mu_\tau} = \frac{\left(1-\eta\frac{y_L^\eta}{\sum_i y_{it}^\eta}\right)}{\left(1-\frac{y_L^\eta}{\sum_i y_{it}^\eta}\right)} \frac{\left(1-\frac{\mathcal{G}_\tau y_L^\eta}{\sum_i y_{it}^\eta}\right)}{\left(1-\eta\frac{\mathcal{G}_\tau y_L^\eta}{\sum_i y_{it}^\eta}\right)} = \frac{1-\frac{y_L^\eta}{\sum_i y_{it}^\eta}(\mathcal{G}_\tau+\eta)+\eta\mathcal{G}_\tau(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2}{1-\frac{y_L^\eta}{\sum_i y_{it}^\eta}(\mathcal{G}_\tau\eta+1)+\eta\mathcal{G}_\tau(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2}$$

Define: $Num \equiv 1-\frac{y_L^\eta}{\sum_i y_{it}^\eta}(\mathcal{G}_\tau+\eta)+\eta\mathcal{G}_\tau(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2$ and $Denom \equiv 1-\frac{y_L^\eta}{\sum_i y_{it}^\eta}(\mathcal{G}_\tau\eta+1)+\eta\mathcal{G}_\tau(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2$ and find that

$$\frac{\partial\frac{\mu_L}{\mu_\tau}}{\partial M} * Denom^2 =$$
$$\left[-\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M}(\mathcal{G}_\tau+\eta) - \frac{y_L^\eta}{\sum_i y_{it}^\eta}\frac{\partial\mathcal{G}_\tau}{\partial M} + 2\mathcal{G}_\tau\eta\frac{y_L^\eta}{\sum_i y_{it}^\eta}\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M} + \eta(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2\frac{\partial\mathcal{G}_\tau}{\partial M}\right] * Denom$$
$$- Num\left[-\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M}(\mathcal{G}_\tau\eta+1) - \frac{y_L^\eta}{\sum_i y_{it}^\eta}\eta\frac{\partial\mathcal{G}_\tau}{\partial M} + 2\eta\mathcal{G}_\tau\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M} + \eta(\frac{y_L^\eta}{\sum_i y_{it}^\eta})^2\frac{\partial\mathcal{G}_\tau}{\partial M}\right]$$

Rearranging the RHS:

$$\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M}\left[Num(\mathcal{G}_\tau\eta+1) - Denom(\mathcal{G}_\tau+\eta) + 2\frac{y_L^\eta}{\sum_i y_{it}^\eta}\mathcal{G}_\tau\eta(Denom-Num)\right]$$
$$+\eta\frac{y_L^\eta}{\sum_i y_{it}^\eta}\frac{\partial\mathcal{G}_\tau}{\partial M}\left[(Num-\frac{Denom}{\eta}) + \frac{y_L^\eta}{\sum_i y_{it}^\eta}(Denom-Num)\right]$$

Note that $\left[(Num-\frac{Denom}{\eta}) + \frac{y_L^\eta}{\sum_i y_{it}^\eta}(Denom-Num)\right] < 0$ for any $\frac{y_L^\eta}{\sum_i y_{it}^\eta} < 1$ since $\eta < 1$ and $Denom > Num$. Since $\frac{\partial\frac{y_L^\eta}{\sum_i y_{it}^\eta}}{\partial M} < 0$ because $\mu'_L < \mu_L$ and because I assume that $\frac{\partial\mathcal{G}_\tau}{\partial M} < 0$, the following condition is sufficient for $\frac{\partial\frac{\mu_L}{\mu_\tau}}{\partial M} > 0$ to hold:

$$\left[Num(\mathcal{G}_\tau\eta+1) - Denom(\mathcal{G}_\tau+\eta) + 2\mathcal{G}_\tau\eta\frac{y_L^\eta}{\sum_i y_{it}^\eta}(Denom-Num)\right] < 0$$

or

$$2\mathcal{G}_\tau\eta\frac{y_L^\eta}{\sum_i y_{it}^\eta}(Denom-Num) < Denom(\mathcal{G}_\tau+\eta) - Num(\mathcal{G}_\tau\eta+1)$$

$$\frac{y_L^\eta}{\sum_i y_{it}^\eta} < \frac{Denom(\mathcal{G}_\tau + \eta) - Num(\mathcal{G}_\tau \eta + 1)}{2\mathcal{G}_\tau \eta (Denom - Num)} = \frac{\mathcal{G}_\tau + \eta}{2\mathcal{G}_\tau \eta} - \frac{Num(\eta - 1)(\mathcal{G}_\tau - 1)}{2\mathcal{G}_\tau \eta (Denom - Num)}$$

Hence, the following condition is more than sufficient for $\frac{\partial \frac{\mu_L}{\mu_\tau}}{\partial M} > 0$ to hold:

$$\frac{y_L^\eta}{\sum_i y_{it}^\eta} < \frac{\mathcal{G}_\tau + \eta}{2\mathcal{G}_\tau \eta} + \frac{Num(1 - \eta)(\mathcal{G}_\tau - 1)}{2\mathcal{G}_\tau \eta (Denom - Num)}$$

If we only consider cases with $M > 2$, then $\frac{y_L^\eta}{\sum_i y_{it}^\eta} < \frac{1}{2}$, and a sufficient condition is:

$$1 < \frac{\mathcal{G}_\tau + \eta}{\mathcal{G}_\tau \eta} + \frac{Num(1 - \eta)(\mathcal{G}_\tau - 1)}{\mathcal{G}_\tau \eta (Denom - Num)}$$

This holds for any value $0 \leq \eta \leq 1$, since it holds for $\eta = 0, 1$ and for $\eta > 0$, the RHS is monotonically declining because $\frac{\partial \frac{\mathcal{G}_\tau + \eta}{\mathcal{G}_\tau \eta}}{\partial \eta} = \frac{\mathcal{G}_\tau \eta - (\mathcal{G}_\tau + \eta)\mathcal{G}}{(\mathcal{G}_\tau \eta)^2} = -\frac{1}{\eta^2}$. Hence, we always have that $\frac{\partial \frac{\mu_L}{\mu_\tau}}{\partial M} > 0$.

C Assumptions on the productivity volatility process

The definition of the steady state implies that aggregate variables are stable, despite a stochastic process on firm-level productivity. This appendix section describes the assumptions I make on the productivity volatility process. I will be referring to the types of firm that are listed in Lemma 1: low productivity firms (which are always unconstrained in steady state), and all types of high productivity firms, both constrained and unconstrained. I will denote the low productivity firms by type L, the unconstrained high-productivity firms by type H^U, and the constrained firms of type τ, where τ measures the number of periods since a firm's most recent positive productivity shock.

A necessary and sufficient condition for the economy to be in steady state, is that the number of firms of each type is constant for all t. In that case, we immediately have that for all t, $F(a(t+1), z(t)) = F(a', z)$ and hence it is clear from the firm decision rules in (52) and the labor market clearing condition (15) that the other aggregate variables $(K_t, \frac{P_t}{w_t})$ and $H(a, k)$ are constant as well. If the number of firms of each type is not constant over time, then necessarily $F(a(t+1), z(t)) = F(a', z)$ is not constant and the economy is not in steady state.

Since the law of large numbers does not hold under a finite M, I will make additional assumptions on the productivity volatility process to ensure that the economy can still be in steady state as defined in (17). Specifically, I will assume that the assignment of productivity shocks is such that, if a certain transition probability Pr_{xy} to go from state x to state y applies to a set of firms of size N_x, then exactly $Pr_{xy}N_x$ firms will transition from state x to state y.[46] What remains to be defined, are the different states x and y.

In the comparative statics exercise in the paper, I am comparing steady states for different values of M. In order to make valid comparisons across different values of M, the productivity volatility process needs to be identical for different M. To then describe a productivity volatility process that is constant across M, it will be useful to keep track of the following implications of Proposition 1. This proposition is demonstrated conditional on the steady state existing for different values of M, as well as the productivity volatility process being identical across M. Hence, if the characteristics of the productivity volatility process are such that the steady state as defined in (17) exists, and that the process is identical across M, then Proposition 1 holds. In order to describe the productivity volatility process, it will be useful to keep in mind the following implications of the model.

- Implication 1: convergence to the optimal level of capital is reached in a finite number of periods and therefore the maximal τ is finite. This is because $\frac{k_H^*}{k_L^*}$ is finite and g_τ does not converge to zero.
- Implication 2: The number of periods it takes for a high productivity firm to become unconstrained is weakly increasing with M.[47] Let therefore T^M denote the number of periods it takes for a high productivity firm to grow out of its financial constraint in a steady state with M firms.
- Implication 3: there are then in total $(T^M + 2)$ types of firms: L, T^M, H^U

The productivity volatility process is then described as follows. Consider a sufficiently high M, $\bar{M}$. Given a specific productivity volatility process, $\bar{M}$ will be the highest value of M considered in the comparative statics on M. Importantly, given implications 1 and 2, we have that $\forall M < \bar{M} : T^M \leq T^{\bar{M}}$.

[46]One could think of the gods setting up a lottery such that exactly $Pr_{xy}N_x$ firms are selected to transition from x to y.

[47]This is because G_τ is weakly decreasing in M and $\frac{k_H^*}{k_L^*}$ is increasing with M.

Based on implication 3, the productivity volatility process will then be defined by transition probabilities across $(T^{\bar{M}}+2)$ "bins" of firms, namely $L, T^{\bar{M}}, H^U_{\bar{M}}$, where $H^U_{\bar{M}}$ denotes the bin with all the unconstrained high productivity firms for $\bar{M}$. Note that this implies that for $M < \bar{M}$, firms might be in e.g. bin $T^{\bar{M}}$ for the definition of their transition probabilities, although they are already unconstrained and thus of type H^U. The transition probabilities across bins are then defined as follows

- Probability to transition from a_L to a_H, i.e. probability to transition from L to $\tau = 1$: P_{LH}. Then, $(1 - P_{LH})$ is probability to remain within L
- Then, for firms with a_H, the transition probabilities are dependent on τ. Conditional on having a_H in period τ, the probability to continue having a_H is $P_{HH\tau}$.
  - Therefore, conditional on having a_H in $\tau = 1$, the probability of still having a_H in $\tau > 1$, is $\prod_{r=1}^{\tau-1} P_{HHr}$
  - Then, the unconditional probability of having a firm in bin $\tau > 1$ is $P_{LH} \prod_{r=1}^{\tau-1} P_{HHr}$
- Finally,the transition probability of moving from bin $H^U_{\bar{M}}$ to bin L, is P_{HL}.

By specificying these bins, and making the transition probabilities between high and low productivity specific to a bin, I have assured that the number of firms in each bin is stable across periods. This can be seen from the following.

- Denote the number of firms in L by M_L
- Number of firms in bin τ: $M_L P_{LH} \prod_{r=1}^{\tau-1} P_{HHr}$
- Number of firms in $H^U_{\bar{M}}$ can be found by setting the number of exiters from $H^U_{\bar{M}}$ equal to the number of entrants in $H^U_{\bar{M}}$: $M_L P_{LH} \prod_{r=1}^{T^{\bar{M}}} P_{HHr} = P_{HL} M_H$. Hence

$$M_H = \frac{M_L}{P_{HL}} P_{LH} \prod_{r=1}^{T^{\bar{M}}} P_{HHr}$$

- One can then also observe that the number of entrants in L equals the number of exiters from L:

$$P_{LH} M_L = P_{LH} M_L \left[(1 - P_{HH1}) + \sum_{\tau=2}^{T^{\bar{M}}} (1 - P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr} \right] + M_H P_{HL}$$

$$P_{LH} M_L = P_{LH} M_L \left[(1 - P_{HH1}) \sum_{\tau=2}^{T^{\bar{M}}} (1 - P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr} \right] + \frac{M_L}{P_{HL}} P_{LH} \prod_{r=1}^{T^{\bar{M}}} P_{HHr} P_{HL}$$

$$1 = (1 - P_{HH1}) + \sum_{\tau=2}^{T^{\bar{M}}} \left[(1 - P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr} \right] + \prod_{r=1}^{T^{\bar{M}}} P_{HHr}$$

Now, note first that $\prod_{r=1}^{T^{\bar{M}}} P_{HHr}$ is the probability, conditional on a firm moving from L to H productivity, that after $T^{\bar{M}}$ periods it still has H productivity. Then note that $\sum_{\tau=1}^{T^{\bar{M}}} (1 - P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr}$ is the probability that a firm moves back to low productivity at some point before $T^{\bar{M}}$. Hence we always have that

$$1 - \prod_{r=1}^{T^{\bar{M}}} P_{HHr} = (1 - P_{HH1}) + \sum_{\tau=2}^{T^{\bar{M}}} (1 - P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr}$$

In other words, the condition for stability of the share of number of firms is always satisfied.[48]

While the described productivity volatility process will ensure that the number of firms in each bin is stable over time, it does not necessarily imply that the number of firms in a bin is an integer. Hence, one has to impose additional restrictions on the values of M under consideration, or the transition probabilities. One such possible restriction is to set $\forall\tau P_{HH\tau} = P_{LH} = P_{LH} = \frac{1}{n}$ and $M_L = n^{(T^{\bar{M}}+x)}$ with $x \geq 2$ and $n \in \mathbb{N}$. This implies that the number of firms in any bin τ is $n^{-\tau} M_L = n^{(T^{\bar{M}}+x-\tau)}$ and in bin H it is n^x.

D 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.[49]

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.

$$y_{it} = k_{it}^{\alpha} l_{it}^{1-\alpha} \tag{50}$$

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).

D.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

[48] Note that $\sum_{\tau=2}^{T^{\bar{M}}} (1-P_{HH\tau}) \prod_{r=1}^{\tau-1} P_{HHr} = 1 - P_{HH1} + (1-P_{HH2})P_{HH1} + (1-P_{HH3})P_{HH1}P_{HH2} + ... + (1 - P_{HHT^{\bar{M}}}) \prod_{r=1}^{T^{\bar{M}}-1} P_{HHr}$, which confirms the equality.

[49] The 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.

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 (50), 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 $\pi_{it}(k_{it}, l_{it}, \mathbf{y_{-it}}) \equiv p_{it}(y_{it}, \mathbf{y_{-it}})y_{it} - w_t l_{it}$:

$$\begin{aligned}\max_{d_{it},k_{it+1},l_{it+1}} \mathcal{L} = &\sum_{t=s}^{\infty} E_s\left[\beta^{t-s} d_{it}\right] + \\ &\sum_{t=s}^{\infty} E_s\left[\lambda_{it}\left(\pi_{it}(k_{it}, l_{it}, \mathbf{y_{-it}}) + P_t\left[(1-\delta)k_{it} - k_{it+1} - d_{it}\right]\right) + \Phi_{it}(d_{it})\right]\end{aligned} \tag{51}$$

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.

$$\begin{aligned}&k_{it+1}\left(z_{it}, F(z(t)), M, L\right)\\ &l_{it+1}\left(z_{it}, F(z(t)), M, L\right)\end{aligned} \tag{52}$$

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.

D.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

$$L = \sum_{i=1}^{M} l_{it} \tag{53}$$

- the goods market clearing condition

$$Q_t = \sum_{i=1}^{M}(x_{it} + d_{it}) + \int_{l \in L} c_{lt} dl \tag{54}$$

- 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.

D.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.

D.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:

$$l_{it} = \left(\frac{(1-\alpha)}{\mu_{it}} \frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \tag{55}$$

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 $\Phi_{it} = 0$.

$$k^* = \mu_U^{\frac{1}{\eta-1}} \frac{Q}{M} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{\eta-\alpha\eta}{1-\eta}} \left(\frac{\alpha}{r_{it}} \right)^{\frac{1+\alpha\eta-\eta}{1-\eta}} \tag{56}$$

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

$$k_{it+1} = (1-\delta)k_{it} + \left(\left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{\eta-\alpha\eta}{1+\alpha\eta-\eta}} - \left(\frac{(1-\alpha)}{\mu_{it}} \right)^{\frac{1}{1+\alpha\eta-\eta}} \right) \left(\frac{P}{w} \left(\frac{Q}{M} \right)^{1-\eta} k_{it}^{\alpha\eta} \right)^{\frac{1}{1+\alpha\eta-\eta}} \tag{57}$$

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 3. *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 $G_\tau = \Pi_{s=0}^{\tau-1}(1+g_s)$ 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, $\frac{P}{w}, \Omega$ - are isomorphic as well, after properly adjusting for the constant productivity. Therefore, this model exhibits analogous comparative statics on M as the baseline model.

E Markup Measurement

The markup measurement is based on De Loecker and Warzynski (2012), who elaborated on the framework introduced by Hall (1986). The main structural assumption for this markup measurement is cost-minimization by firms. Therefore, setup the Lagrangian for cost-minimization on the variable inputs $X^1_{it}, ..., X^V_{it}$,:

$$L_{it}(X^1_{it}, ..., X^V_{it}, K_{it}) = \sum_{v=1}^{V} P^{X^v_{it}} X^v_{it} + r_{it}K_{it} + \lambda_{it}(Q_{it} - Q_{it}(X^1_{it}, ..., X^V_{it}, K_{it}))$$

$$\text{FOC} : \frac{\partial L_{it}}{\partial X^v_{it}} = P^{X^v_{it}} - \lambda_{it}\frac{\partial Q_{it}(.)}{\partial X_{it}} = 0 \Rightarrow \frac{P^Y_{it}}{\lambda_{it}} = \frac{\partial Q_{it}(.) X^v_{it}}{\partial X_{it} Y_{it}} \frac{P^Y_{it} Y_{it}}{P^{X^v_{it}} X^v_{it}}$$

Which implies:

$$\mu_{it} = \frac{\theta^{X^v}_{it}}{\alpha^X_{it}}$$

- Markup $\mu_{it} \equiv \frac{P^Y_{it}}{\lambda_{it}}$,
- the output elasticity for X^v: $\theta^{X^v}_{it} \equiv \frac{\partial Q_{it}(.)}{\partial X_{it}} \frac{X_{it}}{Q_{it}}$
- X's expenditure share in total revenue $\alpha^{X^v}_{it} \equiv \frac{P^{X^v_{it}} X^v_{it}}{P_{it} Q_{it}}$.
  - Note that $\mu_{it} = \frac{\theta^{X^v}_{it}}{\alpha^X_{it}}$ 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 $\alpha^L_{it} \equiv \frac{VA_{it}}{w_t l_{it}}$, where VA_{it} is value added.
  - In some robustness checks, I employ materials as the variable input. In that case, I define $\alpha^M_{it} \equiv \frac{S_{it}}{p^M_t M_{it}}$, where S_{it} is sales and $p^M_t M_{it}$ is expenditure of materials.
- For Cobb-Douglas, θ^X_{it} is constant, so all within-sector variation is driven by α^X_{it}.

F Further stylized Facts

F.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. In general, the relationship here is in line with the findings in Asker et al. (2014).

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**		0.666**		0.565**		0.441**		1.091**		1.053**		0.997**		0.935**	
	(0.0182)		(0.0149)		(0.00490)		(0.00408)		(0.00613)		(0.00300)		(0.00325)		(0.00332)	
$a_{irst-1} - a_{irst-2}$		0.527**		0.469**		0.239**		0.172**		0.612**		0.564**		0.250**		0.187**
		(0.0174)		(0.0163)		(0.00481)		(0.00480)		(0.0158)		(0.0153)		(0.00592)		(0.00601)
a_{irst-1}	0.906**		0.832**		0.660**		0.515**		1.136**		1.087**		1.017**		0.944**	
	(0.0156)		(0.0117)		(0.00533)		(0.00471)		(0.00826)		(0.00423)		(0.00380)		(0.00387)	
a_{irst-2}		0.756**		0.682**		0.309**		0.230**		0.863**		0.804**		0.325**		0.252**
		(0.0151)		(0.0139)		(0.00624)		(0.00603)		(0.0140)		(0.0139)		(0.00756)		(0.00764)
k_{irst}			-0.199**				-0.479**				-0.134**				-0.241**	
			(0.00491)				(0.00480)				(0.00621)				(0.00296)	
k_{irst-1}				-0.187**				-0.254**				-0.141**				-0.226**
				(0.00560)				(0.00843)				(0.00773)				(0.00906)
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.

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

F.2 Markups: urban and rural

Table A.2: Difference in markups: urban versus rural

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

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

G Event Study on Dereservation: Urban/Rural Distinction

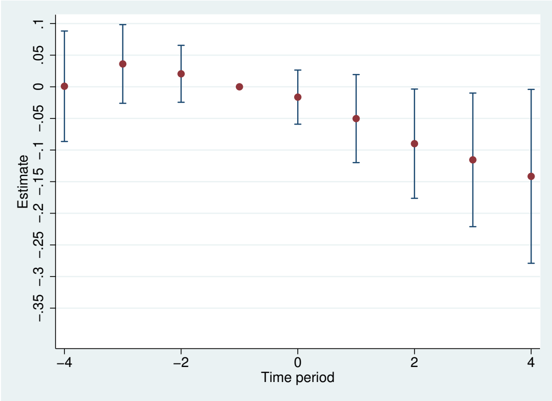
$$y_{irst} = \alpha_{rs} + \gamma_t + \zeta 1(Rural_{irs}) + \sum_{\tau=-4}^{4} \beta_\tau 1(t=\tau) + \sum_{\tau=-4}^{4} \beta_\tau^R 1(t=\tau) * 1(Rural_{irs}) + \varepsilon_{irst} \quad (58)$$

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.[50]

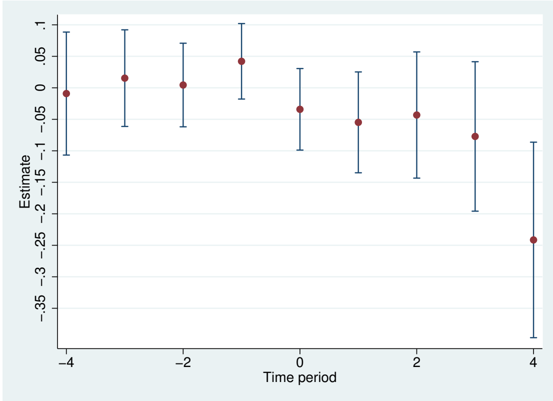
[50]Note that age and geographic location are almost the only contemporaneous dimensions of exogenous heterogeneity for incumbent plants. As such, analyzing heterogeneous treatment effects along this dimension is a valid empirical exercise.

Figure A.1: Dereservation Event-study on Markups and Capital Growth

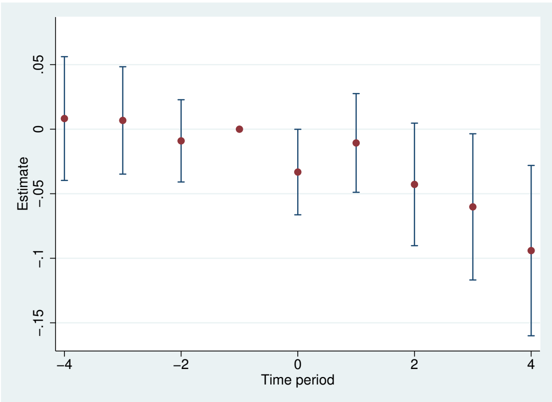
(a) Markup for Urban Plants



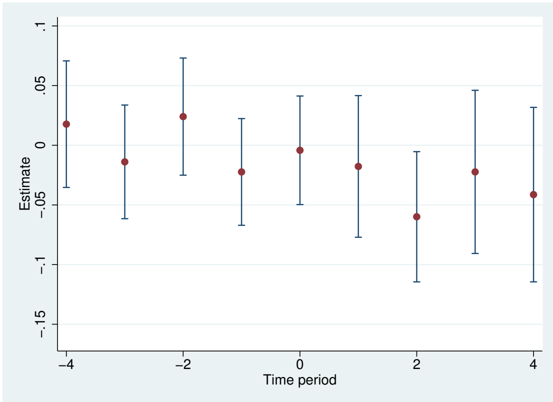
(b) Markup for Rural Plants



(c) $g(k_{irst})$ for Urban Plants



(d) $g(k_{irst})$ for Rural Plants



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.

H 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:

$$l_{it} = \mu_{it}^{\frac{1}{\eta-1}} \frac{Q}{M} a_{it}^{\frac{\eta}{1-\eta}} \left(\frac{P(1-\alpha)}{w} \right)^{\frac{1-\eta+(1-\alpha)\alpha\eta^2}{(1-\eta)(1+\alpha\eta-\eta)}} \left(\frac{\alpha}{\omega_{it}} \right)^{\frac{\alpha}{1-\eta}} \tag{59}$$

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

$$\frac{k_{it}}{l_{it}} = \frac{(1-\alpha)\alpha}{\omega_{it}} \frac{P}{w} \tag{60}$$

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.3: 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