

# Market Power and Growth

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## Abstract

I study the effects of market power on growth in a model with one large firm and a continuum of small firms in each industry. Firms can innovate by creatively destroying their competitors' goods, innovating on their own varieties, and developing new varieties. The key mechanism is that a large firm has a relative preference for creative destruction compared to small firms because creative destruction allows the large firm to take revenue disproportionately from its competitors' goods, and avoid cannibalization. I show that on a balanced growth path, the growth rate in an industry as a function of the large firm's market share displays an inverted-U shape. I calibrate the model to US data and find that the recent rise in the average market share of the largest firm in each industry can explain almost half the fall in growth from the 1990s to the 2010s, as well as the burst in growth during the late 1990s and early 2000s. Large firms maintain their high market shares by creatively destroying their competitors' goods, which ultimately deters other firms from innovating, without generating much growth. I find that subsidizing large firm acquisitions of their competitors' goods (with take-it-or-leave-it offers) increases growth and welfare, but subsidizing large firm acquisitions of small firms and their innovative capacities reduces growth and welfare. Intuitively, a large firm is harmful not because of its size, but because of the way in which it innovates to achieve its size. Acquisitions of small firms' goods shift innovative activity to small firms, who innovate in a more socially optimal way.

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# 1 Introduction

What is the effect of market power on growth? The recent rise in the market shares of large firms has spurred research into the effects of this rise on the macroeconomy, as well as the policy implications.<sup>1</sup> In this paper, I develop a growth model to explore this question in the context of economic growth. The key features of the model are that firms can grow by developing new goods or by creatively destroying other firms' goods, and that each industry consists of a single large firm and a continuum of small firms. I show that with particular parameter assumptions, without computing the full Markov Perfect equilibrium of the industry game, we can solve for the main macroeconomic outcomes as a function of large firms' market shares along a balanced growth path. Across *industries*, the rate of growth as a function of the large firm's market share displays an inverted-U shape, as observed in the data.<sup>2</sup> Across economies, each of which is on a different balanced growth path, the rate of growth is decreasing in the average large firm market share. I calibrate the model to the US economy in the early 1990s and find that, if the observed rise in industry concentration in the US since the 1990s is generated by a fall in the cost of innovation for large firms, then it can explain the burst in growth in the late 1990s, as well as 41% of the fall in the growth rate observed in the data from the early 1990s to the early 2010s. I use the calibrated model to analyze acquisition policies and find that it *reduces* growth and welfare to subsidize large firm acquisitions of small firms and their innovative capacities, but it *increases* growth and welfare to subsidize large firm acquisitions of small firms' goods.

The key mechanism driving the model's results is that compared to small firms, large firms have a relative preference for creatively destroying their competitors' goods over improving their own goods or developing new ones. A new good takes revenue from all other goods in an industry, which is costly for a large firm that produces many of those goods. On the other hand, if a large firm creatively destroys a small firm's good, then the revenue gained comes disproportionately at

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<sup>1</sup>See Autor, Dorn, Katz, Patterson, and Van Reenen (2020), De Loecker, Eeckhout, and Unger (2020), Barkai (2020), and Weiss (2020).

<sup>2</sup>See Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Cavenaile, Celik, and Tian (2021).

the expense of that small firm. A free entry condition at the aggregate level implies that on a balanced growth path, the sum of growth and the rate of creative destruction faced by small firms is pinned down by the cost of entry since each serves as a discount rate on small firm profits. As large firms' market shares grow, innovation shifts away from new good development and toward creative destruction both because a bigger fraction of innovation is from large firms and because large firms focus their innovation even more on creative destruction as they grow. For the free entry condition to hold as creative destruction rises, growth must fall.

Across industries within a single economy, the sum of growth and creative destruction is no longer fixed since entry occurs at the aggregate level, which implies that each industry has the same measure of small firms. Instead, small firm innovation is a decreasing but continuous function of the total discount rate on small firm profits. If heterogeneity across industries in large firm market shares is driven by heterogeneity in their costs of innovation, then more concentrated industries may see more growth due to higher rates of innovation. Nonetheless, if a large firm has a sufficiently high market share, then so much of its innovation is creative destruction of small firms' goods that any further increase in its size implies a fall in growth.

The model thus provides a novel theory of the inverted-U relationship between market concentration and growth across industries. The theory is unrelated to the relative sizes of the “escape competition” and the Schumpeterian effects of competition, unlike previous work.<sup>3</sup> Competition only has the Schumpeterian effect because as some firms innovate more, other firms' incentives to innovate fall. Instead, very large firms reduce growth in their industries by innovating in a way that is particularly harmful to their competitors. An important implication is that widespread higher concentration tends to reduce growth at the aggregate level even if higher concentration within a single industry increases that industry's growth because the entry rate and innovative capacity of the economy are more responsive to widespread changes.

An empirical prediction of the model's main mechanism is that there is heterogeneity across firms in the rate at which their innovations are creatively destroyed. In particular, small firms face higher

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<sup>3</sup>See Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Cavenaile, Celik, and Tian (2021).

creative destruction rates than large firms, and this disparity increased as market concentration rose and growth fell. Even with a low growth rate, small firms are discouraged from entering and innovating.

I use the calibrated model to explore the effects of subsidizing two different types of acquisitions: firm acquisitions in which a large firm purchases a small firm, absorbing their innovative capacity, and good acquisitions in which a large firm purchases a good from a small firm, increasing their market share, but leaving innovative capacities the same. In each case, small firms are paid exactly their value, so they face no incentive to innovate to be acquired. Firm acquisitions reduce growth and welfare: they have the same effect as a fall in large firm innovation costs, namely an increase in large firm market shares and a decrease in growth, except the fall in innovation costs comes at the expense of requiring more small firms to pay entry costs before being acquired. Since large firms' relative preference for creative destruction of their competitors' goods reduces small firm innovation, the model provides an explanation for why large firms acquire their competitors even when a free entry condition holds. As a large firm expands its innovative capacity, it can credibly commit to creatively destroying its competitors' goods.

Subsidizing acquisitions of small firms' goods improves growth and welfare. The policy has the opposite effect of a fall in the cost of innovation for large firms because it discourages large firm innovation. Large firms value the presence of small firms because they present acquisition opportunities. Thus, large firms have less incentive to innovate and take over their industries.

These results highlight an important subtlety in optimal competition policy. Large firms are harmful in the model not because of their size, but because of how they *achieve their size*. Policies that encourage large firm innovation backfire and reduce growth because large firms over-innovate through creative destruction, deterring their competitors from generating growth. Policies that make large firms big without needing to innovate increase growth by shifting innovation to smaller firms that innovate in a more socially optimal way.

## **Related Literature**

The model builds on two different strands of the growth literature, one focused on models of creative destruction<sup>4</sup>, and one on expanding varieties models<sup>5</sup>. Recent work combines the two, but without large firms with positive market shares.<sup>6</sup>

This paper is related to recent papers that study the effect of high productivity or superstar firms on growth.<sup>7</sup> Previous work has mostly considered models with only small firms, and so they focus on the effect of productivity dispersion across small firms, whereas I abstract from productivity dispersion and focus on the effect of large firms' market power. In particular, Aghion, Bergeaud, Boppart, Klenow, and Li (2022) and De Ridder (2021) focus on the channel that increased competition from high productivity competitors reduces less productive firms' markups, and therefore their incentive to grow. The channel I study in this paper is complementary in the sense that they focus on the flow profits a small firm receives from innovating, whereas I focus on the effective discount rate on small firm profits.

Liu, Mian, and Sufi (2022) study a growth model with two large firms in each industry, and find that a large firm can reduce growth by building a substantial productivity advantage over its competitor. The mechanism is that a bigger gap implies that the large firm will optimally cut its price by more in response to innovation by its competitor. On the other hand, as discussed, I focus on how a large firm's innovation decisions affect the rate at which its competitors discount their profits. An important difference is that my mechanism does not rely on a large firm responding directly to the actions of a single competitor. In that sense, my mechanism may be more relevant when thinking about the effect of a large firm on the innovation decisions of small firms. Finally, Cavenaile, Celik, and Tian (2021) study a growth model with large firms, but the pressure those large firms place on small firms has no effect on growth because small firms always have zero profits.

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<sup>4</sup>See Grossman and Helpman (1991b), Aghion and Howitt (1992), Klette and Kortum (2004), and Aghion, Bergeaud, Boppart, Klenow, and Li (2022).

<sup>5</sup>See Romer (1990) and Grossman and Helpman (1991a).

<sup>6</sup>See Atkeson and Burstein (2019).

<sup>7</sup>See Aghion, Bergeaud, Boppart, Klenow, and Li (2022), De Ridder (2021), Cavenaile, Celik, and Tian (2021), and Liu, Mian, and Sufi (2022).

Akcigit and Ates (2021) and Olmstead-Rumsey (2022) propose theories in which exogenous changes in the economy’s innovation technology cause a decline in growth, as well as a rise in market concentration and markups. The theory I propose reverses the causality and suggests that changes in industry structure—a rise in concentration—drive a decline in growth. Moreover, it provides an alternative explanation for the fall in the effect of a patent on a firm’s market value documented in Olmstead-Rumsey (2022): the innovation is more quickly creatively destroyed by a large firm.

The paper proceeds as follows. In section 2, I describe the model. In section 3, I solve the model and discuss optimal firm behavior. In section 4, I characterize analytical results, calibrate the model, and show quantitative results on the effects of a fall in large firms’ innovation costs, and acquisition policies.

## 2 Model

Time is continuous and indexed by  $t \in [0, \infty)$ . There is a unit measure of industries, indexed by  $n \in [0, 1]$ , each of which consists of firms producing differentiated goods. There is a representative household who consumes the numeraire final good and inelastically supplies  $\bar{L}$  units of labor. The household’s preferences are

$$\int_0^\infty e^{-\rho t} \ln(C_t) dt,$$

where  $C_t$  is consumption of the final good. Final good consumption is a Cobb-Douglas aggregate of industry consumption:

$$\ln(C_t) = \int_0^1 \ln(C_{n,t}) dt,$$

where industry consumption is an aggregate of the consumption of the differentiated goods within the industry. The household takes goods prices and the wage,  $W_t$ , as given and chooses the consumption of each good in each industry. The household can also buy and sell a risk-free real bond with net interest rate  $r_t$  (denominated in units of the final good). Going forward, I focus on a particular industry and drop industry subscripts to simplify notation.

## 2.1 Overview and Demand

Since final good consumption is a Cobb-Douglas aggregate of industry consumption, total revenue in an industry is exogenously given as  $R_t$ . The representative household's stochastic discount factor is characterized by the risk-free interest rate  $r_t$ . There is a measure  $M_t$  of goods indexed by  $j \in [0, M_t]$ . The representative consumer has CES preferences across goods with elasticity  $\gamma \geq 1$ : denote consumption of good  $j$  to be  $c_t(j)$  and consumption of the industry good to be  $C_t$ , then

$$C_t = \left( \int_0^{M_t} c_t(j)^{\frac{\gamma-1}{\gamma}} dj \right)^{\frac{\gamma}{\gamma-1}}.$$

Denote the price of good  $j$  by  $p_t(j)$ . The price of the industry good is therefore  $P_t$ , where

$$P_t = \left( \int_0^{M_t} p_t(j)^{1-\gamma} dj \right)^{\frac{1}{1-\gamma}}.$$

The demand curve for good  $j$  is

$$c_t(j) = p_t(j)^{-\gamma} P_t^{\gamma-1} R_t.$$

## 2.2 Production and Competition

There is a large firm, denoted by subscript  $L$ , and a measure  $N_t$  of small firms, indexed by  $i \in [0, N_t]$ . The large firm can produce each good  $j$  with production function

$$q_{L,t}(j) = z_{L,t}(j) l_{L,t}(j),$$

where  $q_{L,t}(j)$  is quantity and  $l_{L,t}(j)$  is labor, which is purchased in a perfectly competitive market at wage  $W_t$ . Each small firm  $i$  can produce each good  $j$  with production function

$$q_{i,t}(j) = z_{i,t}(j) l_{i,t}(j).$$

All varieties of each good produced by different firms are perfect substitutes.

In each moment, firms simultaneously choose prices to maximize static profits. Let  $\bar{z}_t(j)$  be the highest productivity for good  $j$  among all producers, i.e.,

$$\bar{z}_t(j) = \max\{\{z_{i,t}(j)\}_{i \in [0, N_t]}, z_{L,t}(j)\},$$

The evolution of productivity will be such that  $\bar{z}_t(j)$  is always achieved by only a single firm. Let  $\underline{z}_t(j)$  be the second highest productivity, i.e., the maximum among producers other than the firm with productivity  $\bar{z}_t(j)$ . Given that firms compete in prices and produce perfect substitutes of each good, the most productive producer, with productivity  $\bar{z}_t(j)$ , is the sole producer of good  $j$ , and their price is constrained to be weakly less than the marginal cost of the second most productive producer, with productivity  $\underline{z}_t(j)$ .

Define  $\mu_t(j)$  to be the gross markup of price over marginal cost for the producer of good  $j$ :

$$\mu_t(j) = \bar{z}_t(j) \frac{p_t(j)}{W_t}.$$

Let  $Z_t$  be an aggregate of productivity in the industry:

$$Z_t \equiv \left( \int_0^{M_t} \bar{z}_t(j)^{\gamma-1} dj \right)^{\frac{1}{\gamma-1}},$$

and define the relative productivity of good  $j$ :

$$\tilde{z}_t(j) \equiv \frac{\bar{z}_t(j)}{Z_t}.$$

Going forward, I will usually characterize a good by its relative productivity rather than its productivity.

## 2.3 Innovation

In each moment, each firm chooses two types of innovation: a rate of creative destruction for each good  $j$ , and a rate of new good development. Conditional on creatively destroying a good  $j$ , a



firm's relative productivity for that good becomes  $\lambda \tilde{z}_t(j)$ , where  $\lambda > 1$ . Conditional on developing a new good, a firm's relative productivity for that good,  $\lambda \tilde{z}$ , is drawn so that the expected value of  $\tilde{z}^{\gamma-1}$  is equal to 1. Moreover, whenever a firm creatively destroys a good or develops a new good, so that the new relative productivity for that good is  $\tilde{z}_t(j)$ , all other firms are able to produce that good with relative productivity  $\tilde{z}_t(j)/\kappa$ , where  $\kappa > 1$ . Thus  $\kappa$  is the maximum possible gap between the productivities of the most productive and the second-most productive producers of a good. A firm that creatively destroys a good or develops a new good is thus the sole producer of that good (until it is overtaken by creative destruction), but its markup is constrained by the second-most productive producer of that good. To ensure a balanced growth path, the costs of innovation depend on the relative productivity of the good (whether creatively destroyed or newly developed).

To be clear, a firm can creatively destroy a good that it already produces. For small firms, this possibility is irrelevant since each small firm produces an infinitesimal fraction of the goods in an industry. For the large firm, this possibility is meaningful, and implies that the innovative capacity of the economy is not mechanically reduced as the large firm's market share grows.

### 2.3.1 Small Firms

Each small firm  $i$  chooses a creative destruction rate  $x_{C,i,t}(j)$  for each good  $j$ , where subscript  $C$  denotes *creative* destruction, and a new good development rate  $x_{D,i,t}$ , where subscript  $D$  denotes new good *development*. They creatively destroy good  $j$  at Poisson arrival rate  $x_{C,i,t}(j)\Delta$ , where  $\Delta$  is very small so that at Poisson arrival rate  $\int_0^{M_t} x_{C,i,t}(j) dj$ , they creatively destroy a single good, and the relative probability of creatively destroying good  $j$  is proportional to  $x_{C,i,t}(j)$ . A small firm develops a new good at Poisson arrival rate  $x_{D,i,t}$ . The total flow cost in units of labor is

$$\chi_S \left( x_{D,i,t}^\alpha + \chi_C \int_0^{M_t} \tilde{z}_t(j)^{\gamma-1} x_{C,i,t}(j)^\alpha dj \right),$$

where  $\chi_S > 0$  is the small firm innovation cost,  $\chi_C > 0$  is the relative cost of creative destruction compared to new good development, and  $\alpha > 1$  determines the curvature of cost in the innovation

rate.

### 2.3.2 Large Firm

The large firm chooses a creative destruction rate  $x_{C,L,t}(j)$  for each good  $j$ , and a new good development rate  $x_{D,L,t}$ . They creatively destroy good  $j$  at Poisson arrival rate  $x_{C,L,t}(j)$ , and develop new goods at rate  $x_{D,L,t}$ . The total flow cost in units of labor is

$$\chi_L \left( x_{D,L,t}^\alpha + \chi_C \int_0^{M_t} \tilde{z}_t(j)^{\gamma-1} x_{C,L,t}(j)^\alpha dj \right),$$

where  $\chi_L > 0$  is the large firm's innovation cost, and the large firm faces the same relative cost of creative destruction as small firms,  $\chi_C$ .

### 2.3.3 Small Firms vs. The Large Firm

For a small firm, at a Poisson arrival rate they creatively destroy a single good or develop a single new good. Hence, in finite time, a small firm gains control over a finite number of goods. On the other hand, the large firm creatively destroys goods and develops new goods at a continuous rate. Hence, in finite time, the large firm gains control over a finite *measure* of goods. We can think of the large firm as controlling jointly the innovation technologies of a continuum of small firms. Thus, all firms face the same relative cost of creative destruction compared to new good development, and the large firm's innovation cost,  $\chi_L$ , depends on the measure of this continuum of small firms whose innovation technologies it controls. In this sense, the only difference between the large firm and the measure of small firms is that each small firm is infinitesimal and takes the actions of other firms as given, whereas the large firm has market power because it can coordinate its use of the measure of innovation technologies under its control.

### 2.3.4 Parameter Assumption and Discussion

To simplify analysis of the model, I make the following assumption:

**Assumption 2.1.** *The maximum productivity gap between the most productive and second-most productive producers of a good is weakly less than the creative destruction step size and the markup any firm would set if unconstrained, i.e.,  $\kappa \leq \min\{\lambda, \gamma/(\gamma - 1)\}$ .*

It follows that regardless of how a firm became the most productive producer of a good, the gap between that firm's productivity and the productivity of the second-most productive producer of the good is  $\kappa$ . I interpret this assumption as suggesting that firms' goods' are sufficiently imitable so that regardless of the gap between a firm's new innovation (creative destruction or new good development) and whatever came before it, the firm feels the same competitive pressure when pricing that good.

Assumption 2.1 implies that we can interpret new good development as firms innovating on their own goods. In either case, the firm doesn't impose an externality on another firm by destroying their good, and in either case, the firm sets the same markup.

Since Assumption 2.1 implies that all firms set the same markup on all goods, I thus abstract from the effects of firms setting different markups on newly developed goods and on creatively destroyed goods, as well as the effects of large firms setting higher markups than small firms. Allowing for different markups substantially complicates the analysis. As large firms gain market share, they set higher markups, which reduces competition and encourages growth from small firms. This effect is mitigated if large firms are sufficiently more productive than small firms: they may set higher markups than small firms, but lower prices. Then, as large firms gain market share the industry price index falls, as well as small firms' incentive to innovate. Further complications that are potentially interesting but beyond the scope of this paper arise once we allow firms to set different markups and consider the effect on their innovation strategies. Since large firms benefit from higher markups, if small firms set higher markups on newly developed goods, then large firms

prefer to creatively destroy small firms' goods acquired through creative destruction rather than new good development. To properly analyze the case with different markups, it might also make sense to include the possibility of firms innovating on their own goods to increase their markups. Then, large firms would have an additional incentive to creatively destroy small firms' goods, to innovate sufficiently on those goods and set a higher markup than the small firm otherwise would have set.

## 2.4 Entry and Exit

Entry is undirected, so an entering firm draws an industry from the uniform distribution. At each moment in time, there is an infinite mass of potential entrants. If a potential entrant pays the cost of entry, then they draw an industry and enter as a single small firm. Otherwise, the potential entrant receives value 0. The total cost of entry is increasing in the entry rate and is  $E_t^\epsilon$  units of labor, where  $E_t$  is the entry rate and  $\epsilon \geq 1$  is the elasticity of total entry costs with respect to the entry rate. Thus, the marginal entrant faces an entry cost of  $\epsilon E_t^{\epsilon-1}$ . At the lower bound for the elasticity,  $\epsilon = 1$ , the marginal entry cost is constant and there is a free entry condition. At the upper bound for the elasticity,  $\epsilon = \infty$ , the marginal entry cost is 0 if  $E_t < 1$  and infinite if  $E_t > 1$ . In that case, the entry rate is always 1.

Each small firm exits exogenously at Poisson arrival rate  $\eta > 0$ . When a firm exits, it sells each good for which it is the most productive producer to another small firm (not the small firm that is the second-most productive producer of that good).

## 2.5 Equilibrium

At each moment in time, the goods market must clear, i.e., the amount each firm supplies of each good is equal to the representative household's demand for that good, and the labor market must

clear, i.e., the labor used in production, for entry costs, and for innovation costs, must equal the labor inelastically supplied by the representative household.

Given the parameter restriction made in Assumption 2.1, I characterize each good by its type  $f \in \{S, L\}$ , which denotes whether the good's current producer is a small firm ( $S$ ) or the large firm ( $L$ ). Let  $T(j)$  be good  $j$ 's type. For each type  $f \in \{S, L\}$ , define  $\tilde{Z}_{f,t}$  to be an aggregate of the relative productivities of goods of type  $f$  at time  $t$ :

$$\tilde{Z}_{f,t} = \left( \int_{j:T(j)=f} \tilde{z}_t(j)^{\gamma-1} dj \right)^{\frac{1}{\gamma-1}}.$$

It follows that  $\tilde{Z}_{S,t}^{\gamma-1} + \tilde{Z}_{L,t}^{\gamma-1} = 1$ . With that in mind, I only keep track of  $\tilde{Z}_{L,t}$ .

The industry state is the fraction of industry relative productivity in goods produced by the large firm,  $\tilde{Z}_{L,t}$ . The aggregate state is the measure of small firms in each industry,  $N_t$ , and the distribution of industry states across industries.

I study Markov Perfect Equilibria in which firms' markups are given by static optimization of profits and are a function only of  $\tilde{Z}_{L,t}$ . In particular, markups are not a function of the industry aggregate of productivity,  $Z_t$ , the measure of small firms,  $N_t$ , or of time  $t$ . Firms' innovation decisions are given by dynamic optimization of expected discounted profits and are functions only of the industry state,  $\tilde{Z}_{L,t}$ , and the aggregate state when converging to a balanced growth path. Innovation decisions do not depend on  $Z_t$ . Moreover, each firm creatively destroys all goods of each type  $f$  at the same rate. Potential entrants' decisions are given by dynamic optimization of expected discounted profits net of the marginal entry cost and are functions only of the distribution of industry states across industries, and the aggregate measure of small firms.

To be clear, firms can always observe all features of the economy when optimizing, but they suppose that other firms' actions depend only on the variables mentioned above. I show that it is then optimal for each firm also to condition their own actions only on the variables mentioned above.

I focus on balanced growth path equilibria and the convergence to a balanced growth path following unanticipated shocks. A balanced growth path is an equilibrium in which  $\tilde{Z}_{L,t}$  is constant over time in each industry, the measure of small firms  $N_t$  is constant over time,  $Z_t$  grows at a constant rate, and each firm's innovation decisions are functions only of  $\tilde{Z}_{L,t}$  in their industry.

## 2.6 Firm Problem

Before describing the firm problem, note that since small firms take industry aggregates as given, we can split their static profit maximization problem into a separate problem for each good they produce. Moreover, when innovating, we can think of a small firm as receiving the expected present discounted profits from a good upon becoming the most productive producer of that good, and then continuing as an innovator without any consideration of the number of goods they produce.

### 2.6.1 Static Profit Maximization: Prices

At each moment in time, firms choose prices simultaneously to maximize static profits.

**Small Firms:** A small firm that is the most productive producer of a good  $j$  with relative productivity  $\tilde{z}_t(j) = \bar{z}_t(j)/Z_t$  takes as given the industry price index, the wage, and industry revenue, and chooses a markup to maximize static profits:

$$\pi_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t}) = \max_{\mu_t(j)} \left\{ (\mu_t(j) - 1) c_t(j) \frac{W_t}{Z_t \tilde{z}_t(j)} \right\}$$

subject to the demand curve:

$$c_t(j) = \left( \mu_t(j) \frac{W_t}{Z_t \tilde{z}_t(j)} \right)^{-\gamma} P_t^{\gamma-1} R_t,$$

and competition from the second-best producer:

$$\mu_t(j) \leq \kappa.$$

The objective function and demand curve are derived from the fact that  $W_t(Z_t \tilde{z}_t(j))^{-1}$  is the firm's marginal cost. A sufficient industry state is  $\tilde{Z}_{L,t}$ .

**Large Firm:** Let  $J$  be the measurable set of goods for which the large firm is the most productive producer. The large firm takes as given the aggregate of small firms' prices,  $P_{S,t} \equiv \left( \int_{j \notin J} p_t(j)^{1-\gamma} \right)^{\frac{1}{1-\gamma}}$ , the wage, and industry revenue, and chooses markups for goods in  $J$  to maximize static profits:

$$\pi_{L,t}(\tilde{Z}_{L,t}) = \max_{\mu_t(j): j \in J} \left\{ \int_{j \in J} (\mu_t(j) - 1) c_t(j) \frac{W_t}{Z_t \tilde{z}_t(j)} dj \right\}$$

subject to the demand curve for each good  $j \in J$ :

$$c_t(j) = \left( \mu_t(j) \frac{W_t}{Z_t \tilde{z}_t(j)} \right)^{-\gamma} P_t^{\gamma-1} R,$$

competition from the second-best producer of each good  $j \in J$ :

$$\mu_t(j) \leq \kappa,$$

and aggregation:

$$P_t = \left( \int_{j \in J} \left( \mu_t(j) \frac{W_t}{Z_t \tilde{z}_t(j)} \right)^{1-\gamma} dj + P_{S,t}^{1-\gamma} \right)^{\frac{1}{1-\gamma}}.$$

As for the small firm problem, a sufficient industry state is  $\tilde{Z}_{L,t}$ .

### 2.6.2 Dynamic Profit Maximization: Innovation

At each moment in time, firms simultaneously choose innovation rates: a creative destruction rate for each good, and a new good development rate. In the dynamic problem, a firm takes as given its profit function from static optimization.

All small firms choose the same innovation rates. Moreover, we will see that each small firm creatively destroys all goods at the same rate. Thus, let  $x_{C,S,t}$  denote this rate of creative destruction,

and let  $x_{D,S,t}$  denote the rate at which small firms develop new goods. For large firms, let  $x_{C,L,t}(f)$  denote the rate at which a large firm creatively destroys a good that is currently produced by a type  $f \in \{S, L\}$  firm, and let  $x_{D,L,t}$  denote the rate at which a large firm develops new goods.

**Small Firms:** For a small firm to choose their optimal innovation rate, they must know the expected present discounted value of being the most productive producer of a good. They take as given the static profit function at each moment in time, the aggregate state, and the innovation rates of other firms, which imply the evolution of the industry state and the growth rate of industry productivity. The expected present discounted value of producing good  $j$  is given by the HJB equation:

$$\begin{aligned} r_t \bar{\pi}_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t}) = & \pi_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t}) - (x_{C,S,t} + x_{C,L,t}(S)) \bar{\pi}_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t}) - g_t \tilde{z}_t(j) \frac{\partial \bar{\pi}_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t})}{\partial \tilde{z}_t(j)} \\ & + \dot{\tilde{Z}}_{L,t} \frac{\partial \bar{\pi}_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}} + \frac{\partial \bar{\pi}_{S,t}(\tilde{z}_t(j); \tilde{Z}_{L,t})}{\partial t}, \end{aligned}$$

where  $g_t$  is the growth rate of industry productivity, i.e.,  $\dot{Z}_t/Z_t$ , and a dot over a variable indicates its derivative with respect to time. The first term on the right-hand side of the first line is flow profits, the second term reflects the rate at which the good is creatively destroyed, and the third term reflects the rate at which the firm's relative productivity is depreciated by growth in industry productivity either due to creative destruction or new good development. The second line reflects changes in the expected present discounted value of profits over time due to changes in the industry state, or changes in the aggregate state when the economy is converging to a balanced growth path.

A small entrepreneur chooses innovation rates to maximize the expected present discounted value of profits using the household stochastic discount factor, i.e., the risk-free interest rate. Their value



function is thus given by the HJB equation:

$$\begin{aligned}
r_t V_{S,t}(\tilde{Z}_{L,t}) = & \max_{x_{D,t}} \left\{ x_{D,t} \mathbf{E}[\bar{\pi}_{S,t}(\lambda \tilde{z}; \tilde{Z}_{L,t})] - W_t \chi_S x_{D,t}^\alpha \right\} \\
& + \max_{\{x_{C,t}(j)\}} \left\{ \int_0^{M_t} x_{C,t}(j) \bar{\pi}_{S,t}(\lambda \tilde{z}_t(j); \tilde{Z}_{L,t}) dj - W_t \chi_S \chi_C \int_0^{M_t} \tilde{z}_t(j)^{\gamma-1} x_{C,t}(j)^\alpha dj \right\} \\
& - \eta V_{S,t}(\tilde{Z}_{L,t}) + \dot{\tilde{Z}}_{L,t} \frac{\partial V_{S,t}(\tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}} + \frac{\partial V_{S,t}(\tilde{Z}_{L,t})}{\partial t},
\end{aligned}$$

where the first line is the optimization problem for the rate at which the small entrepreneur develops a new good, and the expected value is over realizations of  $\tilde{z}$ , which is distributed so that the mean of  $\tilde{z}^{\gamma-1}$  is 1; the second line is the optimization problem for the rate at which the entrepreneur creatively destroys each good; the third line reflects the entrepreneur's exit rate as well as changes in the value function over time due to changes in the industry state, or change in the aggregate state when the economy is converging to a balanced growth path.

**Large Firm:** The large firm takes as given the aggregate state, the current industry state, as well as small firm behavior as a function of the industry state, and chooses innovation rates to maximize the expected present discounted value of profits, including innovation costs, discounting with the risk-free interest rate. The value function is given by the HJB equation:

$$\begin{aligned}
r_t V_{L,t}(\tilde{Z}_{L,t}) = & \pi_{L,t}(\tilde{Z}_{L,t}) + \max_{\{x_{C,L,t}(j)\}, x_{D,L,t}} \left\{ \dot{\tilde{Z}}_{L,t}(\{x_{C,L,t}(j)\}, x_{D,L,t}; \tilde{Z}_{L,t}) \frac{\partial V_{L,t}(\tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}} \right. \\
& \left. - W_t \chi_L \chi_C \int_0^{M_t} \tilde{z}_t(j)^{\gamma-1} x_{C,L,t}(j)^\alpha dj - W_t \chi_L x_{D,L,t}^\alpha \right\} \\
& + \frac{\partial V_{L,t}(\tilde{Z}_{L,t})}{\partial t}.
\end{aligned}$$

The first term on the right-hand side of the first line is the large firm's flow profits; the second term and the second line are the optimization problem of the large firm choosing innovation rates: the term on the first line is the benefit through changes in  $\tilde{Z}_{L,t}$ , and the second line is the flow cost of innovation. The final line reflects changes in the value function over time due to changes in the aggregate state when the economy is converging to a balanced growth path.

## 2.7 Aggregation and Welfare

Given Assumption 2.1, which implies that all firms set a markup  $\kappa$  on all goods, it follows that the industry price index is  $P_t = \kappa W_t Z_t^{-1}$ , and consumption of the industry good is  $C_t = Z_t L_t^p$ , where

$$L_t^p \equiv \int_0^{M_t} l_t(j) dj$$

is labor used in production, with  $l_t(j)$  the labor used in production of good  $j$ .

Consider an economy in which all industries are identical. Since the final good is the numeraire, the final good price is always 1, and the wage is therefore  $W_t = Z_t/\kappa$ . The interest rate is the sum of the time discount rate and the growth rate of final good consumption:  $r_t = \rho + g_t$ . We can write the representative household's welfare as

$$\int_0^\infty e^{-\rho t} (\ln(Z_t) + \ln(L_t^p)) dt.$$

Along a balanced growth path with growth rate  $g$  and labor used in production  $L^p$ , the household's welfare at time  $t$  is

$$\frac{g}{\rho^2} + \frac{\ln(L^p)}{\rho} + \frac{\ln(Z_t)}{\rho}.$$

## 3 Firm Optimization

### 3.1 Static Optimization: Prices

For brevity, I omit the static optimization problem, and only note that all firms would set a markup weakly greater than  $\gamma/(\gamma - 1)$  if unconstrained by the second-most productive producer.<sup>8</sup> Thus,

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<sup>8</sup>See Edmond, Midrigan, and Xu (2021) for a derivation of the optimal markup with oligopoly, nested CES demand, and Bertrand competition.

by Assumption 2.1, all firms set a markup of  $\kappa$  on all goods. The static profit function for a small firm producing a good with relative productivity  $\tilde{z}$  is thus

$$\pi_{S,t}(\tilde{z}) = \tilde{z}^{\gamma-1} \frac{\kappa - 1}{\kappa} R_t,$$

and for a large firm with relative productivity  $\tilde{Z}_{L,t}$  is

$$\pi_{L,t}(\tilde{Z}_{L,t}) = \tilde{Z}_{L,t}^{\gamma-1} \frac{\kappa - 1}{\kappa} R_t.$$

The industry revenue share of a large firm is  $\tilde{Z}_{L,t}^{\gamma-1}$ .

### 3.2 Evolution of the Industry State and Growth

To solve the dynamic firm problem, we must first understand how the evolution of the industry state and growth of industry productivity depend on the innovation decisions of firms.

The industry state  $\tilde{Z}_{L,t}$  evolves according to

$$\begin{aligned} \frac{\partial \tilde{Z}_{L,t}^{\gamma-1}}{\partial t} = & \lambda^{\gamma-1} \left( x_{D,L,t} + \left( 1 - \tilde{Z}_{L,t}^{\gamma-1} \right) x_{C,L,t}(S) + \tilde{Z}_{L,t}^{\gamma-1} x_{C,L,t}(L) \right) \\ & - \tilde{Z}_{L,t}^{\gamma-1} (N_t x_{C,S,t} + x_{C,L,t}(L)) - (\gamma - 1) \tilde{Z}_{L,t}^{\gamma-1} g_t, \end{aligned}$$

where  $g_t$  is the growth rate of industry productivity,  $Z_t$ :

$$\begin{aligned} (\gamma - 1)g_t \equiv \frac{\partial Z_t^{\gamma-1}/\partial t}{Z_t^{\gamma-1}} = & (\lambda^{\gamma-1} - 1) \left( N_t x_{C,S,t} + \left( 1 - \tilde{Z}_{L,t}^{\gamma-1} \right) x_{C,L,t}(S) + \tilde{Z}_{L,t}^{\gamma-1} x_{C,L,t}(L) \right) \\ & + \lambda^{\gamma-1} (N_t x_{D,S,t} + x_{D,L,t}). \end{aligned}$$

In the evolution of  $\tilde{Z}_{L,t}$  over time, the first line is the inflow due to new good development, creative destruction of small firms' goods, and creative destruction of the large firm's own goods. The first term on the second line is the outflow due to creative destruction of the large firm's goods by small firms and the large firm, and the last term is the outflow due to growth in  $Z_t$ , which reduces relative productivity. In the expression for growth,  $g_t$ , the first line is growth from creative destruction: the  $-1$  in  $\lambda^{\gamma-1} - 1$  reflects the destroyed productivity of the old good; and the second line is growth from new good development in which all the productivity of new goods is novel.

### 3.3 Dynamic Optimization: Innovation

#### 3.3.1 Small Firms

We can write the expected present discounted value of small firm profits from producing a good with relative productivity  $\tilde{z}_t$  as

$$\bar{\pi}_{S,t}(\tilde{z}_t; \tilde{Z}_{L,t}) = \tilde{z}_t^{\gamma-1} \bar{\pi}_{S,t}(\tilde{Z}_{L,t}),$$

where the new definition of  $\bar{\pi}$  is the old definition with  $\tilde{z}_t = 1$ . The First Order Condition for the small firm new good development optimization problem then yields

$$x_{D,S,t}(\tilde{Z}_{L,t}) = \left( \frac{\lambda^{\gamma-1} \bar{\pi}_{S,t}(\tilde{Z}_{L,t})}{\alpha \chi_S} \right)^{\frac{1}{\alpha-1}}. \quad (1)$$

The First Order Condition for the small firm creative destruction optimization problem yields

$$x_{C,S,t}(\tilde{Z}_{L,t}) = \left( \frac{\lambda^{\gamma-1} \bar{\pi}_{S,t}(\tilde{Z}_{L,t})}{\alpha \chi_S \chi_C} \right)^{\frac{1}{\alpha-1}}, \quad (2)$$

where  $x_{C,S,t}(\tilde{Z}_{L,t})$  is the common rate at which a small firm creatively destroys all goods, and so  $M_t x_{C,S,t}(\tilde{Z}_{L,t})$  is the Poisson arrival rate at which a small firm creatively destroys a single good. A small firm creatively destroys all goods at the same rate since the cost and benefit each scale with the relative productivity of the good, and since a small firm does not internalize the different effects that creatively destroying different types of goods will have on the industry.

#### 3.3.2 Large Firm

Whereas small firms develop new goods or creatively destroy old ones to get the expected discounted present value of profits from those goods, the large firm internalizes its impact on the industry. The large firm gets value as a function of the industry state, and innovates to alter that

industry state. Using the evolution of the industry state as a function of the large firm's innovation decisions, the First Order Condition for the large firm's new good development rate yields

$$x_{D,L,t}(\tilde{Z}_{L,t}) = \left( \frac{\lambda^{\gamma-1} (1 - \tilde{Z}_{L,t}^{\gamma-1})}{\chi_L \alpha} \frac{\partial V_{L,t}(\tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}^{\gamma-1}} \right)^{\frac{1}{\alpha-1}}. \quad (3)$$

The term  $1 - \tilde{Z}_{L,t}^{\gamma-1}$  reflects the two ways in which new good development affects the industry state: it increases the productivity of goods produced by the large firm gained through new good development, but it also increases the total productivity in the industry,  $Z_t$ , which depreciates relative productivities. In particular, an increase in total productivity,  $Z_t$ , depreciates the relative productivity of goods produced by the large firm in proportion to the total effective relative productivity of such goods,  $\tilde{Z}_{L,t}^{\gamma-1}$ .

The First Order Condition for the rate at which the large firm creatively destroys its own goods yields

$$x_{C,L,t}(L; \tilde{Z}_{L,t}) = \left( \frac{(\lambda^{\gamma-1} - 1) (1 - \tilde{Z}_{L,t}^{\gamma-1})}{\chi_L \chi_C \alpha} \frac{\partial V_{L,t}(\tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}^{\gamma-1}} \right)^{\frac{1}{\alpha-1}}, \quad (4)$$

and for the rate at which the large firm creatively destroys small firms' goods yields

$$x_{C,L,t}(S; \tilde{Z}_{L,t}) = \left( \frac{1 + (\lambda^{\gamma-1} - 1) (1 - \tilde{Z}_{L,t}^{\gamma-1})}{\chi_L \chi_C \alpha} \frac{\partial V_{L,t}(\tilde{Z}_{L,t})}{\partial \tilde{Z}_{L,t}^{\gamma-1}} \right)^{\frac{1}{\alpha-1}}. \quad (5)$$

When the large firm creatively destroys its own good it is equivalent to developing a new good, except that a portion  $1$  out of the  $\lambda^{\gamma-1}$  of the relative productivity of the new good is taken from one of the large firm's own old goods, and so has no effect on the industry state. When the large firm creatively destroys a small firm's good, we can decompose the effect on the industry state into two components. First, the small firm's good is essentially transferred to the large firm, generating the  $1$  in the numerator. Second, the relative productivity of the good is increased, which has the same effect as when the large firm creatively destroys its own good.

**New Good Development vs. Creative Destruction:** The key mechanism in the model is that, compared to small firms, the large firm has a relative preference for creatively destroying

its competitors' goods over other types of innovation. This mechanism reflects that total effective relative productivity in the industry is fixed at 1, i.e.,  $\tilde{Z}_{S,t}^{\gamma-1} + \tilde{Z}_{L,t}^{\gamma-1} = 1$ , so any gain in relative productivity by one firm must come at the expense of another firm's relative productivity.

Small firm creative destruction relative to new good development is

$$\frac{x_{C,S,t}(\tilde{Z}_{L,t})}{x_{D,S,t}(\tilde{Z}_{L,t})} = \chi_C^{\frac{-1}{\alpha-1}}, \quad (6)$$

which depends only on the cost of creative destruction relative to new good development. The rate at which the large firm creatively destroys its competitors' goods relative to the rate at which it develops new goods is

$$\frac{x_{C,L,t}(S; \tilde{Z}_{L,t})}{x_{D,L,t}(\tilde{Z}_{L,t})} = \chi_C^{\frac{-1}{\alpha-1}} \left( \frac{1 + (\lambda^{\gamma-1} - 1) (1 - \tilde{Z}_{L,t}^{\gamma-1})}{\lambda^{\gamma-1} (1 - \tilde{Z}_{L,t}^{\gamma-1})} \right)^{\frac{1}{\alpha-1}}, \quad (7)$$

which is strictly increasing in its relative productivity share,  $\tilde{Z}_{L,t}$ , and strictly greater than the relative rate for small firms,  $\chi_C^{\frac{-1}{\alpha-1}}$ , as long as  $\tilde{Z}_{L,t} > 0$ . The rate at which the large firm creatively destroys its competitors' goods relative to the rate at which it creatively destroys its own goods is

$$\frac{x_{C,L,t}(S; \tilde{Z}_{L,t})}{x_{C,L,t}(L; \tilde{Z}_{L,t})} = \left( \frac{1 + (\lambda^{\gamma-1} - 1) (1 - \tilde{Z}_{L,t}^{\gamma-1})}{(\lambda^{\gamma-1} - 1) (1 - \tilde{Z}_{L,t}^{\gamma-1})} \right)^{\frac{1}{\alpha-1}}, \quad (8)$$

which is also strictly increasing in  $\tilde{Z}_{L,t}$ , and strictly greater than 1. Comparing equations (6) and (7), we can see that the large firm has a relative preference for creatively destroying its competitors' goods over new good development compared to small firms. In both cases, a small firm does not internalize the effect on other firms' relative productivities. On the other hand, the large firm prefers creative destruction of its competitors' goods because then the relative productivity of its new good comes disproportionately from small firms' goods rather than from its own goods. Similarly, whereas small firms creatively destroy other small firms' goods and the large firm's goods at the same rate, equation (8) shows that the large firm has a relative preference for creatively destroying its competitors' goods over creatively destroying its own goods. Again, creatively

destroying small firms' goods allows the large firm to target where its relative productivity comes from.

Thus, compared to small firm innovation, the large firm's innovation comes disproportionately from creative destruction of small firms' goods.

## 4 Results

### 4.1 Growth and Concentration Along a Balanced Growth Path

I focus first on the distribution of growth across industries and across economies along a balanced growth path, in which each industry is in a steady state equilibrium with a constant  $\tilde{Z}_L$  over time. These results also provide intuition for the quantitative exercises that follow. Without solving for a Markov Perfect Equilibrium of the dynamic game, we can compute the growth rate of an industry or the economy as a function of the market share of the large firm. I omit the time  $t$  subscript.

The following theorem shows that across industries in a single balanced growth path, growth as a function of the large firm's market share exhibits an inverted-U shape.

**Theorem 4.1.** *Suppose  $\alpha \geq 2$  and the economy is on a balanced growth path. Suppose the only heterogeneity across industry parameters is in the large firm's cost of innovation,  $\chi_L$ . The long-run growth rate in an industry is a function of the long-run market share of the large firm,  $g(\tilde{Z}_L)$ . There exists a threshold market share  $Z^*$  such that  $g(\tilde{Z}_L)$  is strictly increasing if  $\tilde{Z}_L < Z^*$  and strictly decreasing if  $\tilde{Z}_L > Z^*$ .*

To gain intuition for the theorem, note that along a balanced growth path, and in the steady state equilibrium of an industry, the expected present discounted value of profits from a good produced

by a small firm with relative productivity 1 is

$$\bar{\pi}_S = \frac{(1 - \kappa^{-1})R}{r + Nx_{C,S} + x_{C,L}(S) + (\gamma - 1)g}, \quad (9)$$

where heterogeneity across industries, driven by heterogeneity in  $\chi_L$ , is in the equilibrium innovation rates,  $x_{C,S}$ ,  $x_{C,L}(S)$ , and  $g$ . The effect of the large firm's market share on growth operates through the effective discount rate on small firm profits, the denominator on the right-hand side of equation (9).

As the large firm's market share increases, there are two effects, the first of which pushes down growth and the second of which pushes growth up. The first effect is due to a shift in the composition of the effective discount rate on small firm profits. We can decompose the non-interest component of the effective discount rate as

$$Nx_{C,S} + x_{C,L}(S) + (\gamma - 1)g = Nx_{C,S} + (\gamma - 1)g_S + x_{C,L}(S) + (\gamma - 1)g_L, \quad (10)$$

where  $g_S$  is growth from small firm innovation and  $g_L$  is growth from large firm innovation. In the steady state equilibrium of an industry, the terms in the decomposition are related by

$$\tilde{Z}_L^{\gamma-1}(Nx_{C,S} + (\gamma - 1)g_S) = \left(1 - \tilde{Z}_L^{\gamma-1}\right)(x_{C,L}(S) + (\gamma - 1)g_L), \quad (11)$$

where the left-hand side is the rate at which relative productivity flows from the large firm to small firms, and the right-hand side is the rate at which relative productivity flows from small firms to the large firm. Holding fixed the effective discount rate on small firm profits, equation (11) shows that as the large firm's market share increases innovation shifts away from small firms, the first two terms on the right-hand side of equation (10), and toward the large firm, the last two terms. Recalling the relative innovation rates of small and large firms, equations (6), (7), and (8), the large firm's ratio of creative destruction of small firms' goods to growth,  $x_{C,L}(S)/g_L$ , is higher than the ratio for small firms,  $x_{C,S}/g_S$ . Thus, the effective discount rate on small firm profits shifts away from growth and toward creative destruction.

The second effect of the large firm's market share on growth is due to an increase in the effective discount rate on small firm profits. The First Order Conditions for small firm innovation imply



that small firm innovation is

$$Nx_{C,S} + (\gamma - 1)g_S = \lambda^{\gamma-1}N \left( \frac{\lambda^{\gamma-1}\bar{\pi}_S}{\alpha\chi_S} \right)^{\frac{1}{\alpha-1}} \left( 1 + \chi_C^{\frac{-1}{\alpha-1}} \right). \quad (12)$$

As the large firm's market share increases and innovation shifts away from small firms, the left-hand side of equation (12) falls. For the right-hand side to fall as well, the effective discount rate on small firm profits increases. Thus, holding fixed the composition of the effective discount rate, growth increases.

When the large firm's market share is sufficiently low, the composition effect is small and the second effect dominates. The large firm's innovation is not so tilted toward creative destruction of its competitors, and the composition of its innovation does not change much in its market share. When the large firm's market share is sufficiently high, the opposite holds and the composition effect dominates.

From this intuition, we also have the following Theorem that compares balanced growth paths across economies.

**Theorem 4.2.** *Suppose  $\alpha \geq 2$  and a free entry condition holds, i.e.,  $\epsilon = 1$ . Suppose there is no heterogeneity across industries. Index the balanced growth path of the economy by the large firm's cost of innovation,  $\chi_L$ , and let labor supply,  $\bar{L}$ , adjust so that final good output,  $C_t$ , relative to productivity,  $Z_t$ , is constant across economies. The long-run growth rate is a strictly decreasing function of the long-run market share of the large firm,  $g(\tilde{Z}_L)$ .*

The free entry condition at the aggregate level, along with holding fixed output relative to productivity, implies that the non-interest component of the effective discount rate on small firm profits is constant across economies indexed by the large firm's cost of innovation. All that remains is the composition effect, which implies that growth falls as the large firm's market share increases. In the quantitative exercise in Section 4.3, I allow output relative to productivity to adjust, but the effect on long-run growth is small relative to the composition effect of the rise in the large firm's market share.

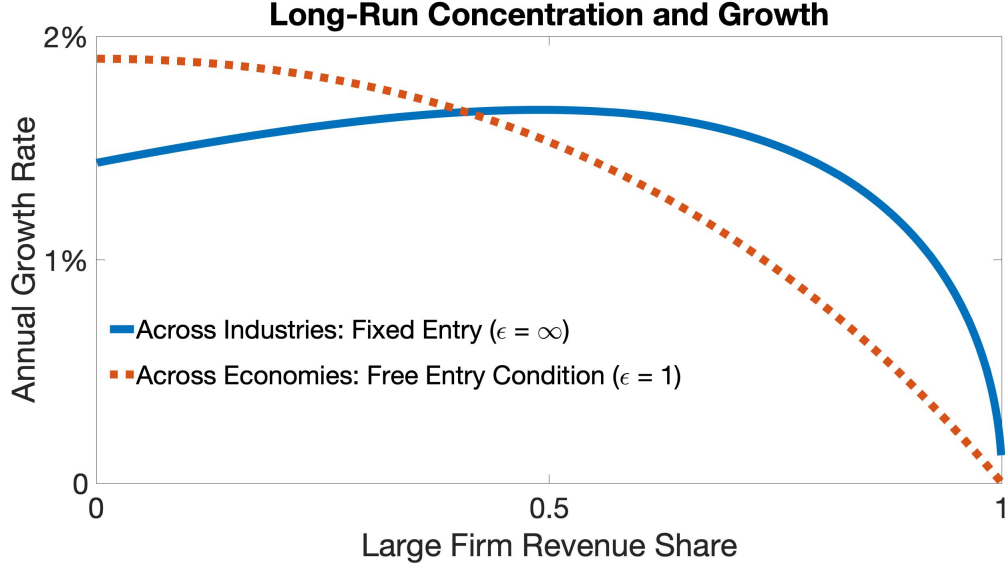


Figure 1: The lines depict the growth rate on a balanced growth path at various levels of the large firm's market share. The solid blue line shows the growth rate across industries on a single balanced growth path, and the dotted red line shows the growth rate across balanced growth paths in different economies, each with constant large firm market shares across industries. The figure is based on the calibration described in Section 4.2.

Figure 1 shows growth as a function of the large firm's revenue share both across industries on a balanced growth path, and across balanced growth paths. Figure 2 shows the two channels through which the large firm's market share effects growth described above. In the left panel, we can see that the magnitude of the effective discount rate increases with the large firm's revenue share across industries. In the right panel, we can see that the rate at which the large firm creatively destroys its competitors' goods relative to the rate at which it generates growth is increasing in its market share. The analogous value for small firms is the value for the large firm when its market share is 0. Equations (10) and (12) show that the large firm's share of the non-interest component of the effective discount rate is  $\tilde{Z}_L^{\gamma-1}$ . Along with the right panel of Figure 2, we can thus see that the composition effect implies a decreasing relationship between the large firm's market and share and growth.

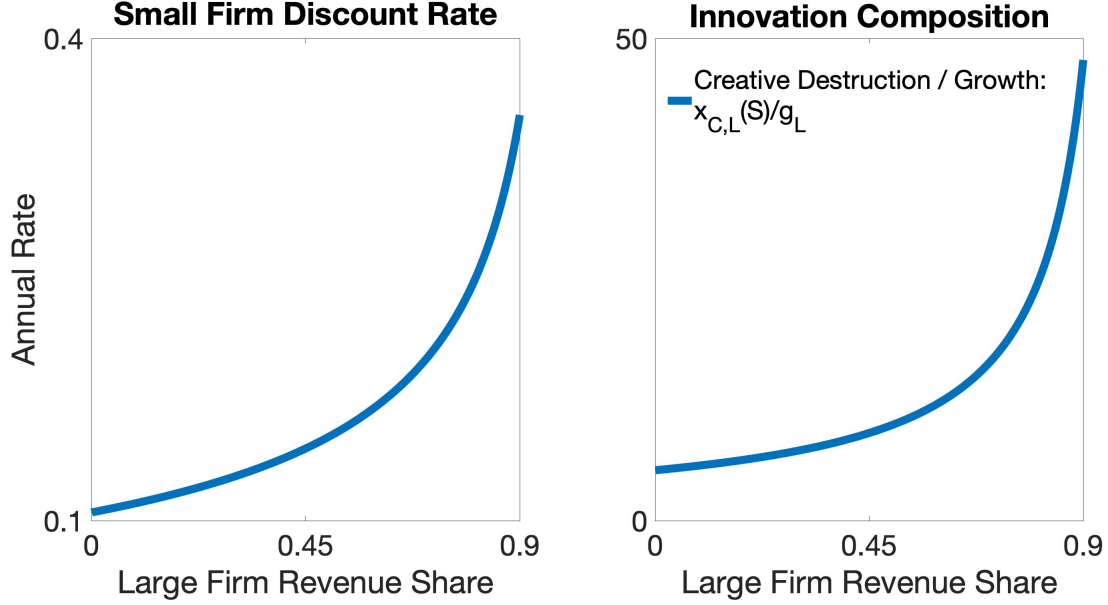


Figure 2: The left panel depicts the effective discount rate on small firm profits minus the interest rate in the steady state equilibrium of an industry as a function of the large firm's market share, on a single balanced growth path. The right panel depicts the rate at which the large firm creatively destroys its competitors' goods relative to the rate at which it generates growth as a function of its revenue share. The figure is based on the calibration described in Section 4.2.

## 4.2 Calibration

I calibrate the model and solve it computationally to yield more results. I first calibrate the model to an initial balanced growth path in which all industries are identical. I set some parameters externally, and internally calibrate the rest to jointly match a set of moments in the data. The externally calibrated parameters as well as their sources are listed in Table 1. The internally calibrated parameters are listed in Table 2. The data moments used to calibrate the internally calibrated parameters as well as their sources are listed in Table 3. I set the minimum productivity gap,  $\kappa$ , equal to the innovation step size,  $\lambda$ , which is the largest possible value given Assumption 2.1. I normalize the final good price to 1 in all periods, and set the household's labor supply,  $\bar{L}$ , so that output in the initial balanced growth path relative to productivity,  $C_t/Z_t = R_t/Z_t$ , is 1. The

units of time are years.

Table 1: Externally Calibrated Parameters

Parameter	Description	Value
$\eta$	Exit Rate	0.04
$\gamma$	Demand Elasticity	3.1
$\alpha$	Innovation Cost Elasticity	2
$\epsilon$	Entry Cost Elasticity	1

The exit rate is from Boar and Midrigan (2022). The demand elasticity is from Broda and Weinstein (2006), using their median estimate from 1990-2001 at the most disaggregated level. The innovation cost elasticity is from Acemoglu, Akcigit, Alp, Bloom, and Kerr (2018). The entry cost elasticity is chosen so that there is a free entry condition at the aggregate level.

The innovation cost elasticity,  $\alpha$ , which I calibrate externally to 2, is particularly important because it determines how a large firm’s innovation composition responds to its market share. I assume that creative destruction and new good development costs are independent, and that each innovation rate responds to the expenditures on that type of innovation as in the studies described in Acemoglu, Akcigit, Alp, Bloom, and Kerr (2018).

Table 2: Internally Calibrated Parameters

Parameter	Description	Value
$\lambda$	Innovation Step Size	1.05
$\chi_C$	Relative Creative Destruction Cost	0.265
$\chi_S$	Small Firm Innovation Cost	2.22
$\chi_L$	Large Firm Innovation Cost	15.14
$\rho$	Time Discount Rate	0.0194

Table 3: Calibration Targets

Moment Description	Data	Model
	Average from 1983-1993	
R&D Relative to GDP	1.81%	1.81%
Creative Destruction Growth Share	26.51%	26.53%
TFP Growth Rate	1.66%	1.66%
Large Firm Market Share	40.68%	40.74%
Real Interest Rate	3.6%	3.6%

The ratio of R&D expenditures on GDP is the Business Enterprise Expenditure on R&D (BERD) relative to GDP from the OECD MSTI database. The creative destruction growth share is the fraction of growth from creative destruction from Garcia-Macia, Hsieh, and Klenow (2019). I compute this value in the model excluding innovation when large firms creatively destroy their own goods because this will appear as innovating on their own goods in the data. The TFP growth rate is from the BLS measure in Garcia-Macia, Hsieh, and Klenow (2019). The large firm market share is the sales-weighted average across 4-digit industries of the largest firm’s revenue share in Compustat from Olmstead-Rumsey (2022). The real interest rate is the 1-year real interest rate from FRED.

The innovation step size,  $\lambda$ , which I calibrate internally to 1.05, is important because it determines the fraction of a creative destruction innovation that replaces an old good,  $1/\lambda^{\gamma-1}$ , and the fraction that is novel. As  $\lambda$  increases and the fraction that is novel goes to 1, the difference between creative destruction and new good development disappears. The calibrated value is consistent with more direct evidence in Garcia-Macia, Hsieh, and Klenow (2019) using data on labor flows, in which the average innovation step size from creative destruction in 1983-1993 is 1.07.

I calibrate the market share of large firms, as well as the shock in Section 4.3, to the average market share of the largest firm in 4-digit industries in Compustat. This measure likely overstates the size of the largest firm since Compustat does not include all firms. An alternative measure is the Census data on industry concentration measures, which show a smaller level of industry

concentration, but a similar rise over the same time period. One downside of the Census data is that it only lists the market share of the top 4 firms in each industry, not the top firm. Moreover, while the Census data is in a sense more accurate because it includes more firms, it may include too many small firms that are not relevant to the mechanism in the model. In the model, if there are many small firms that do not innovate but simply imitate the innovations of others, then the effect may just be to lower the price index by a fixed factor, without any further impact on the decisions of the innovative firms.

### 4.3 The Rise in Concentration and the Fall in Growth

I show that a rise in concentration driven by a fall in the cost of innovation for large firms can explain a portion of the changes in US data since the mid-1990s. In line with the interpretation of the large firm's innovation cost discussed in Section 2.3.3, we can interpret the fall in the cost of innovation as an increase in the concentration of innovative capacity within large firms. The economy begins in the balanced growth path from the calibration in Section 4.2. There is an unanticipated permanent change in  $\chi_L$  in all industries so that the average market share of large firms in the new balanced growth path is 0.51, the sales-weighted average across 4-digit industries of the largest firm's revenue share in 2018 in Compustat from Olmstead-Rumsey (2022) (the large firm innovation cost falls to  $\chi_L = 12.04$ ). I track the transition path of the economy as it converges to a new balanced growth path. Figure 3 shows the average market share of large firms along the transition path. The market share converges over a similar time interval as the gap between the years in the initial calibration, 1983-1993, and the target year for the shock, 2018.

Table 4 compares the main results concerning growth in the model to the data. The model can explain all of the increase in the short-run growth rate in the data if we include growth in output due to changes in output relative to productivity,  $C_t/Z_t$ , as well as changes in productivity. However, the burst in growth does not last as long in the model as in the data: the peak difference in output along the transition path from the original balanced growth path occurs after 4 years and is 42% of the difference in the data after 4 years. The model can explain 41% of the long-run fall in growth,

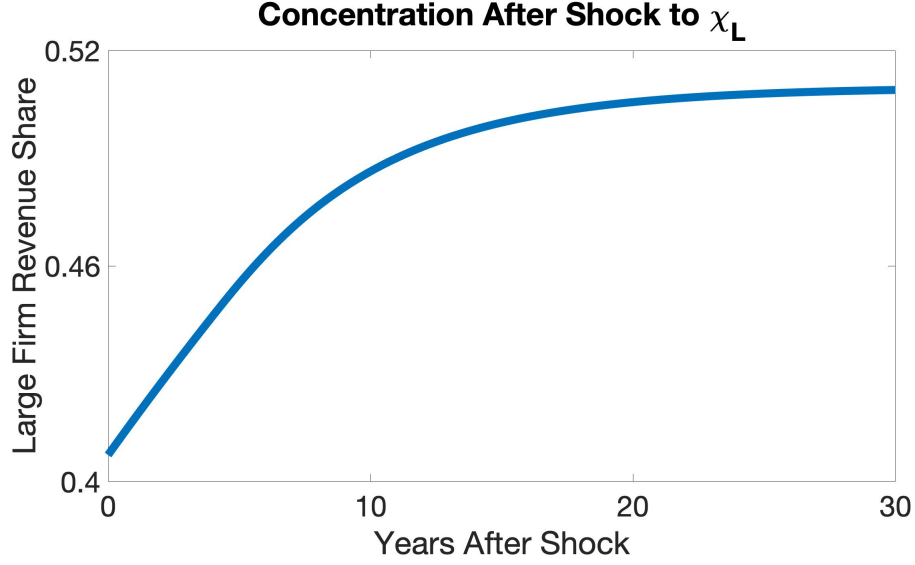


Figure 3: The line depicts the average revenue share of large firms across industries in the economy over time following a shock to  $\chi_L$ .

which in the model is due entirely to a change in the growth rate of productivity,  $Z_t$ , since output relative to productivity is constant along a balanced growth path.

Figure 4 shows annual growth, in real output and in productivity, following the shock. As seen in Table 4, there is a burst in growth immediately following the shock, particularly in output growth but in productivity growth as well, ultimately followed by a decline in the long-run growth rate. Figures 5 and 6 provide a deeper look at the underlying forces. Based on the discussion in Section 4.1 on the small firm effective discount rate, the dashed blue line in Figure 5 shows that the composition effect drives down growth as the large firm's market share grows and innovation shifts toward creative destruction of small firms' goods. The dotted red line shows that in the first few years after the shock, the effective discount rate on small firm profits rises, outweighing the composition effect, and leading to a higher growth rate. However, in the long-run, the effective discount rate is only slightly higher due a small increase in real output relative to productivity, and the composition effect dominates. Figure 6 shows that the large increase in the short-run in the effective discount rate on small firm profits is possible because the entry rate hits its lower

Table 4: Growth After Shock to  $\chi_L$ 

Moment Description	Data	Model
Growth Rate Burst	+0.64 ppt (38.6%) (1993-2003)	Output: +0.87 ppt (52.4%) (first year) TFP: +0.1 ppt (6.0%) (first year)
Cumulative Burst	+6.4 ppt (38.6%) (1993-2003)	Output: +1.07 ppt (16.1%) (4 years) TFP: +0.18 ppt (2.7%) (3 years)
Growth Rate Fall	-0.34 ppt (-20.5%) (2003-2013)	-0.14 ppt (-8.4%) (New BGP)

For each value, ppt is the percentage point rise, and the number in parentheses is the percent rise relative to the initial value. The data are taken from Garcia-Macia, Hsieh, and Klenow (2019). The growth rate burst in the model is the peak growth rate in the short-run following the shock. The output growth rate reflects changes in output relative to productivity,  $C_t/Z_t$ , as well as changes in  $Z_t$ . The cumulative burst is the sum of growth rates, i.e., the peak difference between the new output or productivity path and the old path.

bound of 0; the expected discounted profits of entering become negative, but the measure of small firms can only fall over time as firms exogenously exit. Thus, growth increases because large firms innovate more, and total small firm innovation is slow to fall due to an overhang of small firms. The small increase in the long-run in real output relative to productivity is driven by the fall in long-run entry costs (as well as a fall in innovation costs), which implies an increase in labor used in production.

The large fall in entry in the short-run and the smaller fall in the long-run match the data in Decker, Haltiwanger, Jarmin, and Miranda (2016), which show that the entry rate declined sharply in the mid-to-late 1990s followed by a partial recovery before a large drop during the Great Recession.



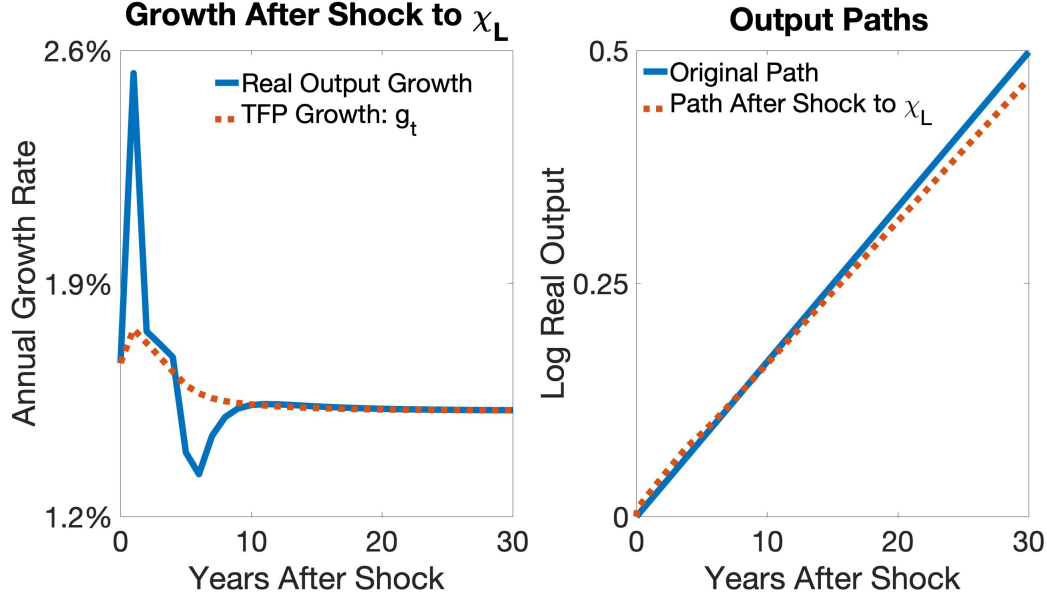


Figure 4: The left panel shows annual growth rates following the shock. The dotted red line is the growth rate of productivity,  $g_t$ , and the solid blue line includes changes in output relative to productivity,  $C_t/Z_t$ , which is constant along a balanced growth path. The right panel shows paths of real output over time. The solid blue line is the original path the economy would have followed had it not been hit by a shock. The dotted red line is the realized path following the shock.

#### 4.3.1 Creative Destruction

Figure 7 shows that the share of growth due to creative destruction falls following the shock, as in the long-run in Garcia-Macia, Hsieh, and Klenow (2019), although by a smaller magnitude. More generally, we can see that a *smaller* share of large firms' growth is due to creative destruction than of small firms' growth. This is not at odds with Figure 2 or with the relative innovation rates in equations (6), (7), and (8) because a large firm only creatively destroys small firms' goods, whereas small firms creatively destroy all firms' goods. Although large firms focus their innovation particularly toward creative destruction of small firm goods, their innovation is less focused on creative destruction overall. Thus, a key prediction of the model is that there is heterogeneity in the rates at which firms' goods are creatively destroyed: small firms, whose goods are creatively

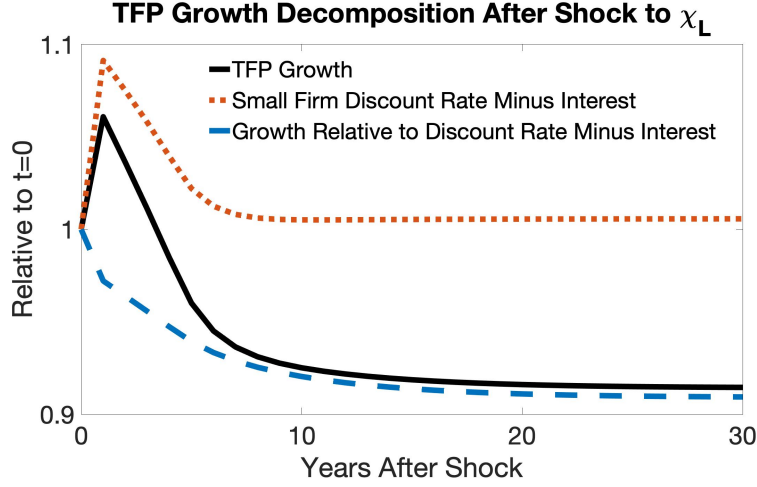


Figure 5: The solid black line depicts the annual productivity growth rate relative to in the original balanced growth path before the shock. The dotted red line and the dashed blue line decompose the black line into the non-interest component of the effective discount rate on small firm profits and growth over the non-interest component of the effective discount rate, respectively, relative to before the shock.

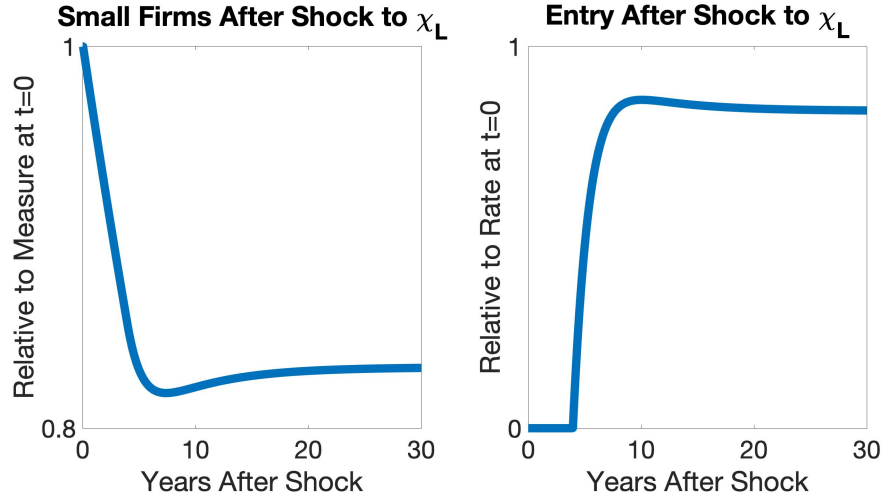


Figure 6: The left panel is the measure of small firms over time relative to the measure before the shock. The right panel is the entry rate over time relative to the entry rate before the shock.

destroyed by all firms, face a higher rate of creative destruction than large firms, who cannot creatively destroy their own goods (if they creatively destroy their own goods, then it appears as large firms improving on their own goods).

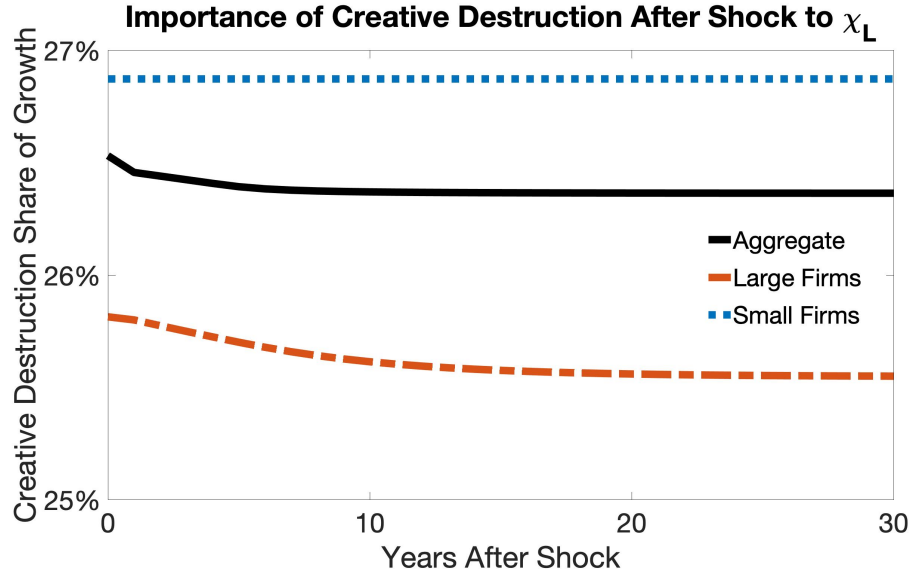


Figure 7: The lines depict the rate of creative destruction of small firms' goods relative to the rate of new good development on a balanced growth path at various levels of the large firm's market share.

#### 4.3.2 Welfare and Size-Dependent Taxes

Taking into account the transition path, welfare defined as the utility of the representative household falls by the equivalent of a permanent 5.84% drop in final good consumption. The decline in the long-run growth rate from the original balanced growth path to the new balanced growth path is ultimately the dominant effect. This suggests that on the margin, contrary to the result in Edmond, Midrigan, and Xu (2021), a tax on firms increasing in their size will improve growth and welfare. For a small tax, large firm prices are unaffected since they are already setting their markups at the constraint implied by the second-best producer. Large firms will respond to the tax by reducing innovation, leading to more small firms and growth and in the long-run. Even if

large firms ultimately respond by investing less in their innovative capacity, the effect on growth and welfare is positive: large firms over-invest in innovative capacity because as their innovation cost,  $\chi_L$ , falls, their profits rise yet welfare falls.

## 4.4 Antitrust Policy: Acquisitions

I use the calibrated model to explore the effects of two different types of acquisition policies: first, for each good produced by small firms, at an exogenous Poisson arrival rate a policymaker acquires the good and transfers it to the large firm in the same industry. Second, for each small entrepreneur, at an exogenous Poisson arrival rate a policymaker acquires the entrepreneur's innovative capacity and transfers it to the large firm in the same industry. The policymaker pays the small firm exactly the value of the good in the first case and the innovative capacity in the second case. Thus, we can think of the policymaker as simply altering the distribution of goods in the first case, and the distribution of innovative capacity in the second case. In each case, since small firms are paid exactly their value, they are only affected through general equilibrium. The policymaker funds the acquisitions with a lump sum tax on the representative household.

### 4.4.1 Small Firm Good Acquisitions

The economy begins on the balanced growth path in the calibrated model following the shock to  $\chi_L$  from Section 4.3. There is an unanticipated permanent increase in the exogenous good acquisition rate from 0 to 5%, so that each good produced by a small firm is transferred to the large firm in the same industry with probability 5% per year. I track the transition path as the economy converges to a new balanced growth path.

Figure 8 shows that productivity growth follows the opposite pattern compared to a decrease in the large firm innovation cost: there is an initial drop, and then an increase in the new balanced growth path. Figure 9 shows the key forces at work. Large firms face less incentive to innovate because the



Figure 8: The line depicts the annual productivity growth rate,  $g_t$ , following the unanticipated increase in acquisitions of small firm goods.

presence of small firms offers acquisition opportunities. Thus, they reduce innovation dramatically, as seen from the path of the average large firm market share excluding the effect of acquisitions. In the short-run growth falls. However, this reduction in innovation lowers the effective discount rate on small firm profits, and leads to a large increase in the entry rate. Ultimately, in the new balanced growth path, there are more small firms, they perform a larger share of innovation, and innovation is tilted away from creative destruction of small firms' goods, and towards growth. In the long-run, growth rises, and taking into account the transition path of the economy, welfare rises by the equivalent of a permanent 4.93% increase in final good consumption.

Along with the benefits of a tax on large firms' size discussed in Section 4.3.2, this result highlights that large firms are harmful in the model not because they are big, but because of how they get big. Thus, it improves welfare to discourage large firm innovation. Even though subsidizing large firms' size and subsidizing large firm acquisitions of small firms' goods both increase large firms' market shares, the former encourages large firm innovation and reduces growth and welfare, but the latter discourages large firm innovation and increases growth and welfare.

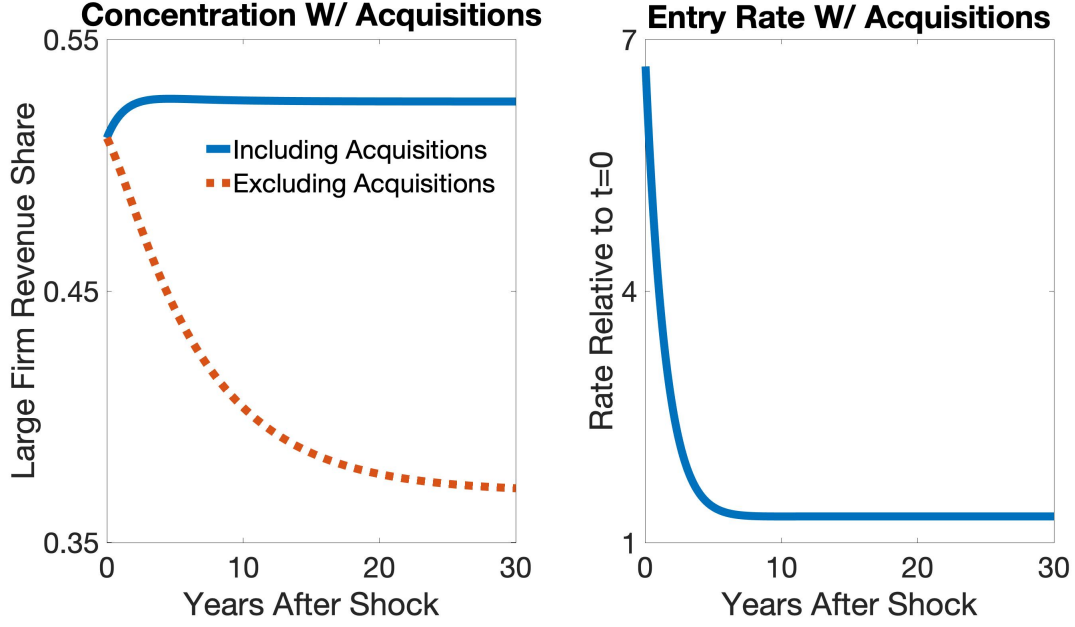


Figure 9: The left panel depicts the average revenue share of large firms following the unanticipated increase in acquisitions (solid blue line), as well as the average revenue share of large firms based only on large firm innovation (dotted red line), i.e., based on optimal firm behavior with acquisitions, but excluding the effect of acquisitions on the relative productivity distribution. The right panel shows the entry rate of small firms relative to the entry rate in the initial balanced growth path.

#### 4.4.2 Firm Acquisitions

The economy begins on the balanced growth path in the calibrated model following the shock to  $\chi_L$  from Section 4.3. There is an unanticipated permanent increase in the exogenous firm acquisition rate from 0 to 1%, so that each small firm's innovative capacity is transferred to the large firm in the same industry with probability 1% per year. I track the transition path as the economy converges to a new balanced growth path.

The effect is largely the same as a fall in the large firm innovation cost, detailed in Section 4.3, except that the increase in large firm innovative capacity comes at the expense of small firm innovative capacity rather than for free. Figure 10 shows that productivity growth increases in

the short-run before dropping precipitously. Unsurprisingly, welfare falls by the equivalent of a permanent 6.18% drop in final good consumption.

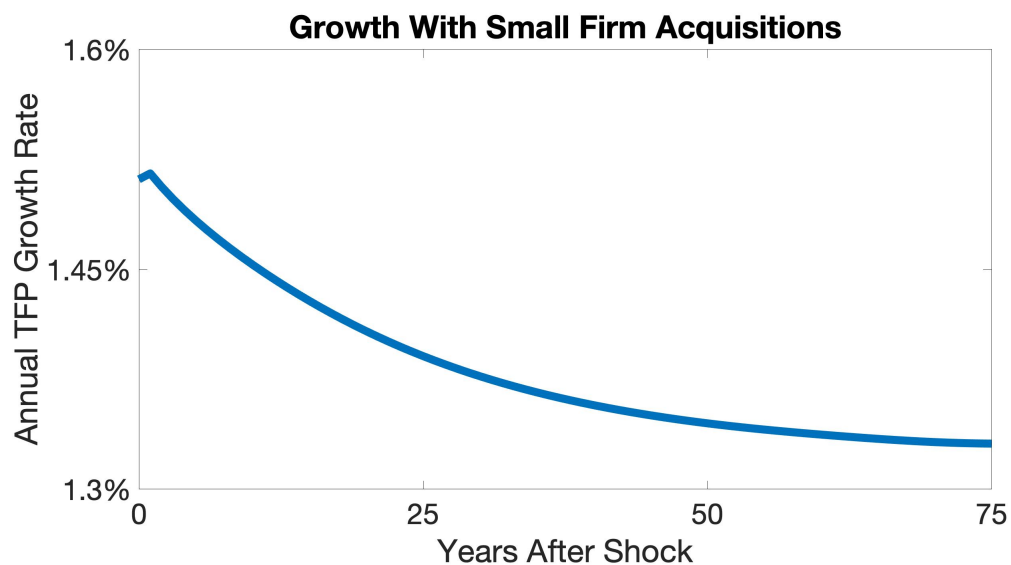


Figure 10: The line depicts the annual productivity growth rate,  $g_t$ , following the unanticipated increase in acquisitions of small firms.

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