The Dynamic Effects of Antitrust Policy on Growth and Welfare *

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Abstract

To shed light on the dynamic effects of antitrust policy on growth and welfare, we develop and estimate the first general equilibrium model with Schumpeterian innovation, oligopolistic product market competition, and endogenous M&A decisions. The estimated model reveals that: (1) Existing policies generate gains in growth and welfare. (2) Strengthening antitrust enforcement could deliver substantially higher gains. (3) The dynamic long-run effects of antitrust policy on social welfare are an order of magnitude larger than the static gains from higher allocative efficiency in production. (4) Current HHI-based antitrust rules leave the majority of anticompetitive acquisitions undetected, highlighting the need for alternative guidelines. Overall, our results suggest that the long-run impact on innovation policy and aggregate productivity growth should receive much higher consideration in the design of antitrust policies.

Keywords: antitrust policy, mergers and acquisitions, innovation, growth, social welfare.
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1 Introduction

In the past decade, several industries in the US have undergone considerable consolidation as a result of increased mergers and acquisitions (M&A) activity. From 2009 to 2018, the number of transactions that were reported to the Federal Trade Commission (FTC) and the Department of Justice (DOJ) under the Hart-Scott-Rodino Antitrust Improvements Act increased steadily from 684 to 2,028 per year. At the same time, the percentage of transactions in which the two authorities issued a second request for information dropped from 4.5% to 2.2%. In 2018, the fraction of reported mergers that were obstructed was only one third of that in 2009.

Concurrent with the increased M&A activity and the decreased rate of merger enforcement challenges brought by the FTC and the DOJ, several studies also document an increase in market concentration, market power, and markups in the US. At the same time, lawmakers and experts alike raise concerns regarding the shortcomings of existing antitrust policies in taking their long-term implications into account.[1] Given these facts, a natural question to ask is whether the existing antitrust laws and their enforcement are sufficient to safeguard the interests of consumers, promote economic growth, and maximize social welfare. Our goal in this paper is to develop and estimate the first structural model of the macroeconomy that focuses not only on market concentration and markups, but also on the long-run effects of antitrust policy on productivity-improving investment by firms, new business entry, and industrial structure.

Our focus constitutes a significant departure from existing work that limits attention to short-run effects in partial equilibrium. The existing literature on antitrust largely focuses on the immediate effects on market concentration and the impact on consumer surplus. Static analyses cannot capture dynamic effects such as the entry and exit of new firms, innovation, and the evolution of the firm productivity distribution. The lack of a general equilibrium framework also means that the effects on long-run output growth are ignored. Our paper is the first to consider these inter-related aspects in a joint framework, and to provide a quantitative assessment of the long-run welfare implications of antitrust policy.

To this purpose, we construct a new quantitative model with three interacting modules: (1) Static product market competition features oligopolistic competition in quantities by an endogenously changing number of large firms with market power, and a mass of small firms that constitute a competitive fringe in each industry. (2) A Schumpeterian step-by-step innovation framework governs strategic innovation decisions by all firms, the emergence (and

[1] For instance, see the "Investigation of Competition in Digital Markets" report by the US Subcommittee on Antitrust, Commercial, and Administrative Law of the Committee on the Judiciary released in 2020 (https://judiciary.house.gov/uploadedfiles/competition_in_digital_markets.pdf).

exit) of new large firms, and new business creation by entrepreneurs. These decisions, in turn, determine the endogenous rate of aggregate productivity growth and transition between industry states. (3) An M&A superstructure is embedded into this framework, where large firms in the same industry can attempt to engage in horizontal M&A. If antitrust authorities do not obstruct the merger, two firms become one, which can potentially improve their relative productivity and market share compared to their peers; but at the same time changes the industrial structure and market concentration in their industry.

Unlike static models in the literature, firms in our model can innovate over time which results in a dynamic competition to improve relative productivity to capture a larger market share. Unlike both the static antitrust models and the endogenous growth literature, we have entry and exit of an endogenous number of superstar firms and an endogenous mass of small firms that constitute a competitive fringe, which are key determinants of market concentration in the long run and should not be ignored. Given the rich firm and industry dynamics, the model is consistent with several crucial empirical regularities, delivers realistic HHI (Herfindahl-Hirschman Index) numbers which allow us to evaluate the efficacy of HHI-based rules adopted in the US, and remains tractable despite its complexity. Due to the observed non-linear relationship between competition and innovation, mergers that reduce consumer surplus and increase market concentration in the short-run can in theory improve or impede economic growth. The complex interactions between the three modules exhibit how daunting a challenge optimal antitrust policy design can be in practice.

The estimation of our model provides a good fit to data on innovation, market concentration, markups, M&A, business dynamism, and the labor share. Importantly, we show that our model is consistent with the observed inverted-U relationship between innovation and market concentration within and across industries. We discipline M&A activity and antitrust enforcement by matching average merger probability, average merger gain, and average obstruction rate of mergers by the DOJ and the FTC. Matching the aforementioned empirical regularities is key to determining the long-run growth and welfare effects of changes in antitrust policy.

Using the estimated model, we conduct a counterfactual experiment where we shut down antitrust enforcement to assess what would happen to efficiency and welfare in its absence. This reveals a welfare loss of 0.49% in consumption-equivalent terms.[2] Next, we conduct two experiments in which we strengthen antitrust enforcement. In particular, in the first experiment, we increase how stringent antitrust authorities are when they decide to investigate merger transactions by lowering HHI thresholds for investigation. In the second experiment, we keep the HHI thresholds for investigation unchanged, but increase the obstruction probability

[2]This number may be interpreted as a lower bound as discussed in Section 5.1.

conditional on investigation. The results from both experiments suggest a significant welfare gain from strengthening antitrust policy enforcement. We find that innovation and the growth rate of the economy increase as a result of the change in policy. This result alone, however, hides interesting heterogeneity across firms in terms of their innovation response. Stronger antitrust enforcement raises innovation by superstar firms. On the other hand, small firms decrease their R&D activity leading to a decrease in the emergence rate of new superstar firms. This is due to the negative impact on the option value of small firms derived from M&A opportunities that are now more likely to be obstructed.

Our key finding is that the dynamic long-run effects of antitrust policy on social welfare are an order of magnitude larger than the effects of static allocative efficiency in production in all of our experiments. Although our results for the relative magnitude of welfare implications are (inescapably and naturally) model-dependent, they suggest that the dynamic consequences of antitrust policy can be much more important than the short-run effects on market concentration. The current antitrust policy that is being enforced by the DOJ and the FTC in the US is openly focused on changes in market concentration. The reported goal of the antitrust authorities is not to maximize static welfare, but consumer surplus (i.e. the producer surplus is ignored). Our results suggest that the long-run impact on the industrial structure and the consequent changes in innovation policy and aggregate productivity growth should receive much higher consideration in the decisions to challenge merger transactions if the goal of the antitrust policy is to maximize social welfare.

Mergers among firms can lower or increase welfare. Socially desirable mergers might occur due to potential synergies between two firms. At the same time, firms can also engage in horizontal mergers to reduce or eliminate competition, due to both static (improving their current market share) and dynamic (lowering the risk of being surpassed in the future) reasons. A question worth investigating is whether the existing guidelines followed by the antitrust authorities are successful in targeting such "anticompetitive acquisitions". According to our results, while such anticompetitive acquisitions are obstructed at a higher rate under the existing rules, the overwhelming majority stay under the radar since the predicted change in HHI remains below the investigation threshold due to the small size of the targets. A primary weakness of existing rules seems to be the inability to capture merger transactions that involve currently small, but potentially very innovative targets that might grow in the future. Devising new methods to detect and obstruct such mergers can therefore further improve growth and social welfare.

Related Literature Our paper addresses a critical gap highlighted in the law literature on antitrust policy. It has caught the attention of the law literature that the current antitrust policy might be inefficient since it has various limitations, including the failure to take into account the effect of innovation and dynamic efficiency gains. Ginsburg and Wright (2012) argue that although models of static competition dominate the modern antitrust analysis and have served antitrust regulation well, they have some drawbacks since they ignore the impact of dynamic competition on future market conditions (such as competition in innovation). Evans and Hylton (2008) argue that the enhanced stature of economists in the federal enforcement agencies may not be sufficient to lead to a substantial improvement in the quality of enforcement decisions due to the tendency to focus on static welfare models at the expense of dynamic competition. Schilling (2015) documents that there is a growing consensus that dynamic efficiency should be the goal of antitrust enforcement. Antitrust agencies should try to strike a balance between short-run static efficiency such as reducing costs and maximizing consumer surplus, and the longer-term gains from innovation and industrial composition. Crandall and Winston (2003) point out that one of the major causes for the ineffectiveness of antitrust policy is the "substantial and growing challenges of formulating and implementing effective antitrust policies in a new economy characterized by dynamic competition, rapid technological change and important intellectual property." Sidak and Teece (2009) find that using static models to address antitrust issues in a dynamic economy is unlikely to improve consumer welfare, and a more dynamic analytical framework would increase the likelihood of helping rather than hurting consumers. Kaplow (2021) summarizes the literature highlighting the deficiencies linked to existing HHI-based antitrust policies, such as the failure to capture entry, innovation, dynamics, and general equilibrium implications of mergers. Despite the increasing attention to the importance of taking into account innovation and the associated dynamic efficiency gains when designing antitrust policy, a dynamic general equilibrium model with Schumpeterian innovation, realistic product market competition, and endogenous M&A decisions is still absent in the literature. We make the first attempt at offering such a unified framework to shed light on the dynamic effects of antitrust policy on growth and welfare.

Our paper also adds to the economics literature which focuses on the effects of competition policy, and of antitrust policy in particular. The rationale behind the enforcement of antitrust policy finds its roots in economic theory which suggests that some mergers might result in a substantial increase in market concentration and prices, and lower consumer surplus. For instance, Farrell and Shapiro (1990) show that horizontal mergers with Cournot oligopoly and homogenous goods necessarily lead to price increases in the absence of synergies. Evidence that mergers lead to higher prices can be found, for instance, in Ashenfelter and Hosken (2010), Dafny, Duggan, and Ramanarayanan (2012), Ashenfelter, Hosken, and Weinberg (2015), and Miller and Weinberg (2017).[3] Using a static oligopoly model, Alviarez, Head, and Mayer (2020) estimate positive effects of antitrust policies on consumer surplus when taking

[3]See Kwoka (2014) and Philippon (2019) for literature reviews.

into account changes in markups and efficiency gains following multinational acquisitions in the beer and spirits markets. In a recent paper, Gutiérrez and Philippon (2018) use the differential evolution of market concentration between the US and the European Union to establish a positive relationship between prices and market concentration empirically. They further show that stronger enforcement of antitrust policies is associated with a significant decrease in market concentration and profitability.

Another aspect that is crucial to understand the welfare implications of antitrust policies is the dynamic response of firms to mergers and acquisitions, in particular in terms of industry innovation following a merger. For instance, Buccirossi, Ciari, Duso, Spagnolo, and Vitale (2013) and Gutiérrez and Philippon (2018) provide empirical evidence that stronger antitrust enforcement is associated with faster growth in total factor productivity in a set of OECD countries and in the European Union. Mermelstein, Nocke, Satterthwaite, and Whinston (2020) propose a partial equilibrium dynamic industry model in which firms can either merge or invest in physical capital to reduce marginal costs. They also show that dynamic considerations affect the optimal level of antitrust enforcement. Compared to their model, we build a general equilibrium model with endogenous growth populated by heterogenous industries in which the number of large and small firms is endogenous and results from investment in innovation. While they consider optimal antitrust policy (without commitment), we focus on the welfare implication of existing HHI-based antitrust rules and propose a quantification of the welfare and growth effects of antitrust enforcement. From a theoretical perspective, the effect of antitrust policy on innovation is potentially ambiguous. The change in market concentration resulting from a merger has two opposing forces on innovation incentives. In particular, higher competition reduces average profits and hence innovation incentives. On the other hand, it raises the incentive to invest in innovation in order to escape competition. This can result in an inverted-U relationship between innovation and competition as highlighted in Aghion, Bloom, Blundell, Griffith, and Howitt (2005).[4]

Despite the concerns raised by the law literature on the neglected dynamic effects of antitrust policy on innovation, there is no available dynamic macroeconomic framework to quantify the growth and welfare implications of antitrust policies. The goal of this paper is to fill this gap in the existing literature and offer a new realistic framework to study the welfare implications of antitrust policy. David (2020) proposes a search and matching model of mergers and acquisitions in which merging firms can improve their productivity through synergies. He uses the model to study the aggregate implications of mergers and acquisitions in general equilibrium. Due to the assumption of perfect competition, the efficiency gains from

[4] Aghion, Bloom, Blundell, Griffith, and Howitt (2005) further provide empirical evidence supporting this hump-shaped relationship using data from the UK.

antitrust enforcement cannot be calculated. Although the model does not feature antitrust concerns, it can be used to calculate an estimate of the foregone efficiency gains due to synergy losses from antitrust enforcement, which represents a potential upper bound on its detrimental impact. Compared to his model, our model features differentiated products, markups, and investment in innovation, which allow us to incorporate the potential benefits of antitrust policies. Within the endogenous growth literature, the closest attempt to theoretically study the effect of antitrust policies on innovation is Aghion, Harris, Howitt, and Vickers (2001). They propose a Schumpeterian growth model with duopolistic competition within industry and show how innovation is related to product market competition as measured by the elasticity of substitution within product markets, and hence antitrust policy.[5] Compared to that model, our framework allows for a more realistic description of industries, and explicitly models mergers and antitrust policy. Each industry in our model comprises an endogenous number of large firms and an endogenous mass of (small) price-taking firms, and features endogenous emergence of large firms through innovation, entry of small firms, and a non-degenerate distribution of markups, sales, and R&D expenditures. Importantly, our model can generate the inverted-U shape relationship between innovation and competition that has been documented, for instance, in Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Cavenaile, Celik, and Tian (2019) without any ex-ante heterogeneity. Our model can also generate realistic HHI numbers, which is a feature missing in endogenous growth models with Bertrand competition and homogeneous goods – the dominant paradigm in this literature.[6] These features allow us to directly map our model to the actual HHI-based rules followed by antitrust authorities when reviewing merger transactions and to offer a quantitative evaluation of the dynamic growth and welfare effects of antitrust policies.

This paper is complementary to previous finance literature on antitrust policy which largely focuses on the short-run effects of antitrust policy on firm profitability and stock return. Stillman (1983) uses daily stock return data of rival firms around horizontal merger events that were challenged by the antitrust authorities and finds that the majority of rivals do not exhibit abnormal returns of any kind. He concludes that the government has brought cases against horizontal mergers that were not expected by investors to have any appreciable effect on product prices. Dissanaike, Drobetz, and Momtaz (2020) find that regulatory merger

[5] Segal and Whinston (2007) also theoretically investigate the effect of different types of antitrust policies on innovation in stationary models with continual innovation by an incumbent firm and potential entrant(s) in a partial equilibrium framework.

[6] Most endogenous growth models assume either monopolistic competition or Bertrand competition with homogeneous goods. This results in unrealistic industry-level outcomes such as one firm dominating the whole market and producing 100% of industry output (and a 50-50 split in neck-and-neck industries as a special case). While this provides tractable solutions, such degenerate sales distributions cannot be mapped to the data. Given that this structure can only yield an HHI of 100% or 50%, one cannot evaluate the actual HHI-based antitrust policy implemented by the DOJ and the FTC.

control reduces the profitability from corporate acquisitions and impedes the efficiency in the M&A market since the uncertainty in merger decisions reduces takeover threat. Grullon, Larkin, and Michaely (2019) find that over 75% of US industries have experienced an increase in concentration levels, and firms in industries with the largest increases in product market concentration show higher profit margins and more profitable mergers and acquisitions deals. They argue that lax enforcement of antitrust regulations and increasing technological barriers to entry may be important factors behind this trend. Although a large strand of previous literature documents the short-run impact of antitrust policy on firm profits and stock returns, relatively less is known about its long-run dynamic effects on social welfare and economic growth. Our paper aims to fill this gap.

The rest of the paper is structured as follows: In Section 2, we introduce the model. Section 3 contains our structural estimation of the model and a discussion of data moments that we target. Section 4 contains our quantitative analysis of the estimated economy and the counterfactual experiments. Section 5 presents some extensions to the baseline model, and the associated changes in the quantitative results. Section 6 concludes.

2 Model

In this section, we develop a new general equilibrium model with imperfect competition between an endogenous number of superstars and an endogenous mass of small firms in each industry, combined with a step-by-step Schumpeterian growth model as in Cavenaile, Celik, and Tian (2019), and a merger and acquisition (M&A) market subject to search frictions.

2.1 Environment

Preferences Time is continuous and horizon is infinite. The representative household maximizes lifetime utility given by:

$$U = \int_0^\infty e^{-\rho t} \ln(C_t) \; dt \tag{1}$$

where $\rho > 0$ is the discount rate and C_t is consumption of the final good at time t.

The household inelastically supplies one unit of labor and receives a wage rate w_t. Households own all the assets in the economy. Household wealth (A_t) evolves over time according to:

$$\dot{A}_t = r_t A_t + w_t - P_t C_t \tag{2}$$

where r_t is the rate of return on assets and P_t is the price of the final good at time t.

Final Good Production The final good (Y_t) is produced competitively using a Cobb-Douglas production function over inputs from a continuum of industries:

$$\ln(Y_t) = \int_0^1 \ln(y_{jt}) \; dj \tag{3}$$

where y_{jt} is production of industry j at time t.

Industry Production Each industry is populated by an endogenous number ($N_{jt} \in \{1, ..., \bar{N}\}$) of superstar (large) firms, each producing a differentiated variety, as well as by a competitive fringe composed of a mass m_{jt} of small firms producing a homogeneous good. As a result, small firms in the competitive fringe are price takers. We allow for strategic interaction between superstar firms which compete statically *à la* Cournot. Production of industry j at time t is given by:

$$y_{jt} = \left(\sum_{i=1}^{N_{jt}} y_{ijt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \tag{4}$$

where y_{ijt} is the production of superstar firm i in industry j at time t, y_{ckjt} is the production of small firm k in industry j competitive fringe at time t, $\tilde{y}_{cjt} = \int_{F_{jt}} y_{ckjt} \; dk$ is the total production of the competitive fringe in industry j at time t, F_{jt} is the set of small firms in the fringe in industry j at time t and $\eta > 1$ is the elasticity of substitution between varieties.

Variety Production Superstar firms and small firms in each industry produce using a linear production technology in labor:

$$y_{ijt} = q_{ijt} l_{ijt} \text{ and } y_{ckjt} = q_{ckjt} l_{ckjt} \tag{5}$$

where q_{ijt} (q_{ckjt}) is the productivity and l_{ijt} (l_{ckjt}) the labor of superstar firm i (small firm k) in industry j at time t.

We assume that small firms in the same competitive fringe share the same productivity level $q_{ckjt} = q_{cjt}, \forall k$. Superstar firms differ in terms of productivity which they can build over time through innovation.

R&D and Innovation Superstars can invest in R&D to improve their productivity. Superstar i must pay a cost in terms of units of the final good equal to

$$R_{ijt} = \chi z_{ijt}^{\phi} Y_t. \tag{6}$$

in order to generate a Poisson rate z_{ijt} of success in R&D.

If innovation is successful, it raises productivity by a factor $\lambda > 0$. We assume that the relative productivity between any two superstars in the same industry is at most $(1+\lambda)^{\bar{n}}$ with $\bar{n} \geq 1$. The relative productivity of small firms with respect to the industry leader $\zeta = \frac{q_{cjt}}{q_{jt}^{leader}}$ is assumed to be constant.

Entry and Exit of Superstar Firms Despite being price takers, small firms can nevertheless invest in R&D. By paying a cost (in terms of final good)

$$R_{kjt}^{e} = \nu X_{kjt}^{\epsilon} Y_t, \tag{7}$$

a small firm k in the competitive fringe can generate a Poisson arrival density X_{kjt} of entry into superstar firms when $N_{jt} < \bar{N}$.

A successful small firm joins the set of superstar firms in the industry (unless $N_{jt} = \bar{N}$, in which case entry into superstars is not allowed). It raises the number of superstar firms in the industry by one and starts as the smallest superstar firm in the industry, i.e. $\bar{n}$ steps behind the industry leader.

By homogeneity within the fringe, each small firm in the same industry performs the same level of R&D, and we can rewrite the industry level Poisson rate of innovation $X_{jt} = \int X_{kjt} dk = m_{jt} X_{kjt}$, and the industry level R&D expenditures of small firms $R_{jt}^{e} = m_{jt} R_{kjt}^{e}$.

In addition, superstar firms can also endogenously exit the set of superstar firms, and become a small firm. This happens when a superstar firm falls more than $\bar{n}$ steps behind the industry leader. The endogenous entry and exit of superstar firms generate an endogenous distribution over the number of superstar firms per industry.

Entry and Exit of Small Firms Our model also allows for entry and exit of small firms, offering realistic firm dynamics and life cycle. In particular, the economy is populated by a mass one of entrepreneurs who can invest to create a new (small) firm. By paying a cost of $\psi e_t^2 Y_t$ units of the final good, they can generate a Poisson rate e_t of starting a new small firm. In case of success, the newly created firm joins the competitive fringe of a randomly allocated industry. We further assume that successful entrepreneurs sell their firm on a competitive market at its full value and remain in the set of entrepreneurs so that the mass of entrepreneurs remains constant over time. As a result, the mass of small firms in each industry remains constant as well: $m_{jt} = m_t, \forall j$.

Mergers and Acquisitions and Antitrust Policy At any instant t, a firm i in industry j faces an arrival rate σ of having the opportunity to merge with any other firm k in the same industry. If the opportunity arises, firms i and k can decide to merge. There is a cost associated with merger φY_t where φ is drawn from a distribution with cumulative distribution function $G(\varphi)$. We assume that a share θ of the surplus (net of merger cost) from the merger goes to the acquiring firm (which is assumed to be the larger firm). If both firms have the same size, the surplus is split equally between the two firms. As a result, they find it profitable to merge if the expected value of the newly created firm exceeds the joint value of the two pre-existing firms plus the merger cost. If they decide to merge, both firms are replaced by a single firm producing a single product with a new productivity level (q_M) equal to:

$$q_M = \gamma q_A^{\alpha} q_T^{1-\alpha} \tag{8}$$

where q_A is the productivity of the acquiring firm and q_T is the productivity of the target firm, $\gamma > 1$, and $\alpha \in (0, 1)$.[7] In case the resulting productivity level does not fall on the quality ladder, we use linear interpolation to obtain a new productivity level that falls on the quality ladder as follows:

$$n_M = \begin{cases} ceil\left(\mathcal{D}\right), & \text{w.p. } P^u = 1 - \frac{(1+\lambda)^{ceil(\mathcal{D})} - \frac{q_M}{q_L}}{(1+\lambda)^{ceil(\mathcal{D})} - (1+\lambda)^{ceil(\mathcal{D})-1}} \\ ceil\left(\mathcal{D}\right) - 1, & \text{w.p. } P^d = 1 - P^u \end{cases} \tag{9}$$

where q_L is the productivity of the industry leader before the merger, n_M is the number of productivity steps by which the newly created firm leads the pre-merger leader in the industry and $\mathcal{D} = log_{1+\lambda}\left(\frac{q_M}{q_L}\right)$.[8]

In addition, even when a merger would be profitable from the merging firms' point of view, antitrust authorities can decide to prevent the merger from happening. Antitrust policy in our model is summarized by a function ($\mathcal{A}_{ikj}$) which equals one if the merger between firms i and k in industry j is allowed and zero otherwise. We model antitrust policy in a way that is consistent with the guidelines set by US antitrust authorities. Depending on the initial level of concentration in the industry and the resulting change in concentration following the merger, antitrust authorities can either allow the merger or proceed to further investigation. If the merger does not meet the requirement for outright authorization and is

[7] This merger technology is similar to that used in David (2020) and Celik, Tian, and Wang (2019).
[8] Notice that the newly created firm is allowed to become or remain the industry leader.

subject to further investigation, the merger is not allowed with probability ι. ι captures the uncertainty surrounding merger cases subject to further investigation by antitrust authorities. In particular, we follow the specification from Appendix B1 in Taragin and Loudermilk (2019) which reflects the US Department of Justice guidelines:

$$\mathcal{A}_{ikj} = \begin{cases} 1 & \text{if } \frac{HHI_M}{\kappa} < 0.15 \text{ or } \frac{\Delta HHI_M}{\kappa} < 0.01 \\ 1 & \text{w.p. } 1-\iota \text{ if } \frac{HHI_M}{\kappa} \geq 0.15 \text{ and } \frac{\Delta HHI_M}{\kappa} \geq 0.01 \\ 0 & \text{w.p. } \iota \text{ if } \frac{HHI_M}{\kappa} \geq 0.15 \text{ and } \frac{\Delta HHI_M}{\kappa} \geq 0.01 \end{cases} \tag{10}$$

where $\kappa > 0$ is a parameter, HHI_M is the post-merger Herfindahl index where the market share of the merged firms is equal to the sum of their original market shares and ΔHHI_M is the change in the Herfindahl index resulting from the merger.

2.2 Equilibrium

Household's problem Household lifetime utility maximization delivers the standard Euler equation:

$$\frac{\dot{C}_t}{C_t} = r_t - \rho. \tag{11}$$

Final Good Producers The final good is produced under perfect competition. Without loss of generality, we normalize the price of the final good $P_t = 1, \forall t$. The representative final good producer chooses the quantity of each variety to maximize profit:

$$\max_{[\{y_{ijt}\}_{i=1}^{N_{jt}}, \tilde{y}_{cjt}]_{j=0}^{1}} \quad \exp\left(\frac{\eta}{\eta-1}\int_0^1 \ln\left[\sum_{i=1}^{N_{jt}} y_{ijt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}}\right] dj\right) - \int_0^1 \left(\sum_{i=1}^{N_{jt}} p_{ijt}y_{ijt} + p_{cjt}\tilde{y}_{cjt}\right) dj. \tag{12}$$

where p_{ijt} (p_{cjt}) is the price of variety i (the fringe variety) in industry j at time t. This gives the following inverse demand functions:

$$p_{ijt} = \frac{y_{ijt}^{-\frac{1}{\eta}} Y_t}{\sum_{k=1}^{N_{jt}} y_{kjt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}}} \tag{13}$$

and

$$\frac{y_{ijt}}{y_{kjt}} = \left(\frac{p_{kjt}}{p_{ijt}}\right)^{\eta} \tag{14}$$

where y_{ijt} should be replaced by $\tilde{y}_{cjt}$ for the competitive fringe.

Variety Producers We assume Cournot competition between superstar firms within an industry. Superstar firms maximize profit:

$$\max_{y_{ijt}} \; p_{ijt}y_{ijt} - w_t l_{ijt} = \max_{y_{ijt}} \; \frac{y_{ijt}^{\frac{\eta-1}{\eta}} Y_t}{\sum_{k=1}^{N_{jt}} y_{kjt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}}} - \frac{w_t y_{ijt}}{q_{ijt}}, \tag{15}$$

which delivers best response functions:

$$y_{ijt} = \left[\frac{\eta-1}{\eta} q_{ijt} \frac{\sum_{k\neq i} y_{kjt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}}}{\left[\sum_{k=1}^{N_{jt}} y_{kjt}^{\frac{\eta-1}{\eta}} + \tilde{y}_{cjt}^{\frac{\eta-1}{\eta}}\right]^2} \frac{Y_t}{w_t}\right]^{\eta} \tag{16}$$

$$= \frac{\eta-1}{\eta} q_{ijt} \frac{\sum_{k\neq i} \left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}{\left[\sum_{k=1}^{N_{jt}} \left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}\right]^2} \frac{Y_t}{w_t} \tag{17}$$

Total production of the fringe is given by:

$$\tilde{y}_{cjt} = q_{cjt} \frac{\frac{Y_t}{w_t}}{\sum_{k=1}^{N_{jt}} \frac{y_{kjt}}{\tilde{y}_{cjt}}^{\frac{\eta-1}{\eta}} + 1} \tag{18}$$

Using equations (17) and (18), we can show that relative production within an industry is given by:

$$\left(\frac{y_{ijt}}{y_{kjt}}\right)^{\frac{1}{\eta}} = \frac{q_{ijt}}{q_{kjt}} \frac{\sum_{l\neq i} \left(\frac{y_{ljt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}{\sum_{l\neq k} \left(\frac{y_{ljt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}} \tag{19}$$

$$\left(\frac{y_{ijt}}{\tilde{y}_{cjt}}\right)^{\frac{1}{\eta}} = \frac{\eta-1}{\eta} \frac{q_{ijt}}{q_{cjt}} \frac{\sum_{l\neq i} \left(\frac{y_{ljt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}{\sum_{l=1}^{N_{jt}} \left(\frac{y_{ljt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}} + \left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}. \tag{20}$$

Within each industry j, equations (19) and (20) constitute a system of N_{jt} equations in N_{jt} production ratios. We can solve this system of equations given relative productivities within the industry.

We can further show that markups (M_{ijt}) and profits before R&D expenditures (π_{ijt}) are heterogeneous and are functions of relative productivities within the industry:

$$M_{ijt} = \frac{\eta}{\eta-1}\frac{\sum_{k=1}^{N_{jt}}\left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}+\left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}{\sum_{k\neq i}\left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}+\left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}} \tag{21}$$

$$\pi_{ijt} = \frac{Y_t}{\left[\sum_{k=1}^{N_{jt}}\left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}+\left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}\right]^2}\frac{\eta+\sum_{k\neq i}\left(\frac{y_{kjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}+\left(\frac{\tilde{y}_{cjt}}{y_{ijt}}\right)^{\frac{\eta-1}{\eta}}}{\eta} \tag{22}$$

Value Function and Superstar R&D Decision Given static decisions, the relevant state variables for a firm i in industry j at time t can be summarized by the vector of the number of productivity steps between superstar firm i and every other superstar firm $k\backslash\{i\}$ in the industry. Letting n_{ijt}^k be the number of steps by which firm i in industry j leads firm k at time t, the relevant state variables for firm i in industry j at time t are given by the vector $\mathbf{n}_{ijt} = \{n_{ijt}^k\}_{k\neq i}$.[9]

Henceforth, we drop the industry and time subscripts unless otherwise needed. We further define the function $T(\mathbf{n}_i)$ as:

$$T(\mathbf{n}_i) = \begin{cases} \mathcal{E} & \text{if } \exists n_i^k : n_i^k < -\bar{n} \\ \mathbf{n}_i\backslash\{n_i^k : \exists l, n_i^k - n_i^l > \bar{n}\}\backslash\{n_i^k : n_i^k > \bar{n}\} & \text{otherwise} \end{cases} \tag{23}$$

Starting from any vector $\mathbf{n}_i$, the function $T(\mathbf{n}_i)$ replaces the vector $\mathbf{n}_i$ by $\mathcal{E}$ if firm i is more than $\bar{n}$ steps below any other firm in the same industry. In that case, firm i is not a superstar firm. Second, the function $T(\mathbf{n}_i)$ removes from the vector $\mathbf{n}_i$ any other firm that is not a superstar, i.e. a firm that is more than $\bar{n}$ steps below any other firm in the same industry. We define a state such that $T(\mathbf{n}_i) = \mathbf{n}_i$ as a legal state. In the rest of the paper, we assume that the initial states at time zero are legal states.

[9] Relative productivities can be rewritten as $\frac{q_{ijt}}{q_{kjt}} = (1+\lambda)^{n_{ijt}^k}$.

A superstar firm i chooses an innovation rate (z_i) to maximize its value given by:

$$
\begin{aligned}
rV(\mathbf{n}_i) = \quad & \max_{z_i} \underbrace{\pi(\mathbf{n}_i)}_{\text{Profit flow}} - \underbrace{\chi z_i^{\phi} Y}_{\text{R\&D cost}} \\
& + \underbrace{z_i \left[V(T(\mathbf{n}_i + \mathbf{1})) - V(\mathbf{n}_i)\right]}_{\text{Own innovation}} \\
& + \underbrace{\sum_{k \neq i} z_k \left[V(T(\mathbf{n}_i \backslash \{n_i^k\} \cup \{n_i^k - 1\})) - V(\mathbf{n}_i)\right]}_{\text{Others' innovation}} \\
& + \underbrace{X \left[V(\mathbf{n}_i \cup \{\min\{\bar{n}, \bar{n} + \min(\mathbf{n}_i)\}\}) - V(\mathbf{n}_i)\right]}_{\text{Entry of a new superstar}} \\
& + \underbrace{\sum_{k \neq i} 2\mathbb{E}[\mathcal{A}_{ik}]\mathcal{B}_{ik}\sigma \int \left(\max\left\{0, \mathbb{E}[V(T(\mathbf{n}_M^{ik}))] - \varphi Y - V(\mathbf{n}_i) - V(\mathbf{n}_k)\right\}\right) dG(\varphi)}_{\text{Mergers between the current firm and firm } k} \\
& + \underbrace{\sum_{k \neq i} \sum_{l \neq i,k} \mathbb{E}[\mathcal{A}_{kl}]\mathcal{M}_{kl}\sigma \left[\mathbb{E}[V(T(\mathbf{n}_M^{kl}))] - V(\mathbf{n}_i)\right]}_{\text{Mergers between two other firms } k \text{ and } l} \\
& + \underbrace{\dot{V}(\mathbf{n}_i)}_{\text{Firm value growth}}
\end{aligned} \tag{24}
$$

where $V(\mathcal{E}) = 0$, $\mathcal{A}_{ik} = 1$ if the merger between firm i and k is allowed by antitrust policy and zero otherwise, σ is the rate at which a merger opportunity arises, $\mathbf{1}$ is a vector of ones of appropriate dimension, $\mathbf{n}_M^{ik} = \mathbf{n}_i \backslash \{n_i^k\} + (n_M^{ik} - \min\{0, \min(\mathbf{n}_i)\})\mathbf{1}$ is the step size vector of the firm resulting from a merger between firms i and k where n_M^{ik} is given by equations (8) and (9), $\mathbf{n}_M^{kl} = \mathbf{n}_i \backslash \{n_i^k\} \backslash \{n_i^l\} \cup \{\min\{0, \min(\mathbf{n}_i)\} - n_M^{kl}\}$ is the step size vector of firm i after a merger between firms k and l ($k \neq i$ and $l \neq i$) and $\mathcal{M}_{kl} = 1$ if firms k and l find it profitable to merge (i.e. if the merger generates a positive expected surplus net of merger costs) and zero otherwise. $\mathcal{B}_{ik}$ determines the share of the merger surplus that goes to firm i:

$$
\mathcal{B}_{ik} = \begin{cases} \theta & \text{if } n_i^k > 0 \\ \frac{1}{2} & \text{if } n_i^k = 0 \\ 1 - \theta & \text{if } n_i^k < 0 \end{cases} \tag{25}
$$

In equation (24), the first line is the flow profit minus the cost of R&D. The second line is the change in firm value due to a successful innovation by firm i which happens with Poisson rate z_i. If firm i innovates, it increases its lead to any other firm by one. Any firm $\bar{n}$ productivity steps below firm i exits (the set of superstars).

The third line comes from any other firm innovating. In that case, the lead of firm i with respect to the innovating firm decreases by one. If firm k led firm i by $\bar{n}$ steps, then firm

i exits. In addition, if the innovating firm k is also leading any other firm l by $\bar{n}$ (which happens if $n_i^l - n_i^k = \bar{n}$), firm l exits. The fourth line is the effect of firm entry on the value of firm i. In that case, the entrant starts $\bar{n}$ productivity steps below the industry leader. The fifth line corresponds to a profitable merger between firms i and k. The sixth line is the effect of a merger between any two firms other than firm i in the industry. The last line is the growth in firm value.

We can guess and verify that, in a balanced growth path, $V(\mathbf{n}_i) = v(\mathbf{n}_i)Y$. In that case, $\dot{V}(\mathbf{n}_i) = gv(\mathbf{n}_i)Y$ (where g is the growth rate of Y). Using equation (11), we can write:

$$
\begin{aligned}
\rho v(\mathbf{n}_i) = \quad & \max_{z_i} \frac{\pi(\mathbf{n}_i)}{Y} - \chi z_i^{\phi} \\
& + z_i \left[v(T(\mathbf{n}_i + \mathbf{1})) - v(\mathbf{n}_i) \right] \\
& + \sum_{k \neq i} z_k \left[v(T(\mathbf{n}_i \backslash \{n_i^k\} \cup \{n_i^k - 1\})) - v(\mathbf{n}_i) \right] \\
& + X \left[v(\mathbf{n}_i \cup \{\min\{\bar{n}, \bar{n} + \min(\mathbf{n}_i)\}\}) - v(\mathbf{n}_i) \right] \\
& + \sum_{k \neq i} 2\mathbb{E}[\mathcal{A}_{ik}]\mathcal{B}_{ik}\sigma \int \left(\max\left\{0, \mathbb{E}[v(T(\mathbf{n}_M^{ik}))] - \varphi - v(\mathbf{n}_i) - v(\mathbf{n}_k)\right\} \right) dG(\varphi) \\
& + \sum_{k \neq i} \sum_{l \neq i,k} \mathbb{E}[\mathcal{A}_{kl}]\mathcal{M}_{kl}\sigma \left[\mathbb{E}[v(T(\mathbf{n}_M^{kl}))] - v(\mathbf{n}_i) \right]
\end{aligned}
$$

The optimal level of innovation is given by:

$$
z_i = \left\{ \frac{v(T(\mathbf{n}_i + \mathbf{1})) - v(\mathbf{n}_i)}{\chi \phi} \right\}^{\frac{1}{\phi - 1}}. \tag{26}
$$

Small Firm Innovation and Entry into Superstar Firms Define $\Theta = (N, \vec{n})$ as the state of the industry with $N \in \{1, ..., \bar{N}\}$ being the number of superstars in the industry and $\vec{n} \in \{0, ..., \bar{n}\}^{N-1}$ denoting the number of steps followers are behind the leader (in ascending order). We let $f(\Theta) = \frac{1}{\eta - 1} \ln \left(\sum_{i=1}^{N(\Theta)} \left(\frac{y_i}{y_c}(\Theta) \right)^{\frac{\eta - 1}{\eta}} + 1 \right)$ and define $p_{li}(\Theta)$ as the arrival rate of a leader innovation and $p(\Theta, \Theta')$ as the instantaneous flows from state Θ to Θ'. By symmetry within the fringe, each small firm in industry Θ (with $N(\Theta) < \bar{N}$) chooses R&D investment to maximize:

$$
\begin{aligned}
rV^e(\Theta) \quad = \quad & \max_{X_{kj}} X_{kj} V(\{\tilde{\mathbf{n}}_j - \bar{n}\} \cup \{-\bar{n}\}) - \tau V^e(\Theta) - \nu X_{kj}^{\epsilon} Y \\
& + \sum_{\Theta'} p(\Theta, \Theta')(V^e(\Theta') - V^e(\Theta)) + \dot{V}^e(\Theta)
\end{aligned} \tag{27}
$$

where $V^e(\Theta)$ is the value of a small firm in industry j with industry state Θ and $\tilde{\mathbf{n}}_j = \mathbf{n}_{kj}$, where k denotes a productivity leader in industry j.[10]

Guessing and verifying that, in a BGP, $V^e(\Theta) = v^e(\Theta)Y$, we can rewrite:

$$(\rho+\tau)v^e(\Theta) = \max_{X_{kj}} X_{kj} v(\{\tilde{\mathbf{n}}_j - \bar{n}\} \cup \{-\bar{n}\}) - \nu X_{kj}^{\epsilon} + \sum_{\Theta'} p(\Theta,\Theta')(v^e(\Theta') - v^e(\Theta)) \tag{28}$$

The optimal innovation intensity by a small firm in industry j is then:

$$X_{kj} = \left(\frac{v(\{\tilde{\mathbf{n}}_j - \bar{n}\} \cup \{-\bar{n}\})}{\nu\epsilon}\right)^{\frac{1}{\epsilon-1}} \tag{29}$$

Plugging in the optimal solution, the normalized value of a small firm is given by:

$$v^e(\Theta) = \frac{1}{\rho+\tau}\left[\left(1-\frac{1}{\epsilon}\right)\frac{v(\{\tilde{\mathbf{n}}_j - \bar{n}\} \cup \{-\bar{n}\})^{\frac{\epsilon}{\epsilon-1}}}{(\nu\epsilon)^{\frac{1}{\epsilon-1}}} + \sum_{\Theta'} p(\Theta,\Theta')(v^e(\Theta') - v^e(\Theta))\right] \tag{30}$$

Entrepreneurs and Entry into the Competitive Fringe The expected value of a new small firm created by a successful entrepreneur is equal to: $W = \sum_{\Theta} V^e(\Theta)\mu(\Theta)$, where $\mu(\Theta)$ is the mass of industries of type Θ.[11] The value of being an entrepreneur (S) can then be written as:

$$\rho S = \max_{e} -\psi e^2 Y + eW \tag{31}$$

We guess and verify that, in a BGP, $S = sY$, so that:

$$e = \frac{W}{2\psi Y} = \frac{\sum_{\Theta} v^e(\Theta)\mu(\Theta)}{2\psi} \tag{32}$$

which implies:

$$s = \frac{\left[\sum_{\Theta} v^e(\Theta)\mu(\Theta)\right]^2}{4\psi\rho} \tag{33}$$

[10] Note that we use $\int_{k=i} V_k^e(\Theta)dk = 0$ in the first term, i.e. the value of the small firm is insignificant compared to the value of the superstar firm it becomes, since it is of mass zero in the competitive fringe.

[11] We can show that the expected value of $\sum_{\Theta'} p(\Theta,\Theta')(V^e(\Theta') - V^e(\Theta))$ in a stationary equilibrium is equal to zero (see Proposition 1 in Appendix A.1). W is thus equal to $\frac{1-\frac{1}{\epsilon}}{\rho+\tau}\frac{\int_0^1 V(\{\tilde{\mathbf{n}}_j - \bar{n}\} \cup \{-\bar{n}\})^{\frac{\epsilon}{\epsilon-1}}\, dj}{(\nu\epsilon)^{\frac{1}{\epsilon-1}}}$.

In a BGP, entry and exit of small firms are equalized implying:

$$e = \tau m \tag{34}$$

Combining equations (32) and (34), we get:

$$m = \frac{\sum_{\Theta} v^e(\Theta)\mu(\Theta)}{2\psi\tau} \tag{35}$$

Equilibrium Definition An equilibrium is defined as a set of allocations $\{C_t, Y_t, y_{ijt}, y_{ckjt}\}$, policies $\{l_{ijt}, l_{ckjt}, z_{ijt}, X_{kjt}, e_t, \mathcal{M}_{ikjt}\}$, prices $\{p_{ijt}, p_{cjt}, w_t, r_t\}$, the number of superstars in each industry N_{jt}, a mass of small firms m_t, a set of vectors $\{\mathbf{n}_{ijt}\}$ that denote the relative productivity distance between firm i and every other firm in the same industry j at time t, such that, $\forall t \geq 0$, $j \in [0,1]$, $i \in \{1, ..., N_{jt}\}$:

(i) Given prices, final good producers maximize profit.

(ii) Given $\mathbf{n}_{ijt}$ and N_{jt}, superstars choose y_{ijt} to maximize profit.

(iii) Given prices, small firms in the competitive fringe choose y_{ckjt} to maximize profit.

(iv) Superstar firms choose innovation policy z_{ijt} to maximize firm value.

(v) Small firms choose innovation policy X_{kjt} to maximize firm value.

(vi) Conditional upon a meeting, superstar firms choose merger policy $\mathcal{M}_{ikjt}$ to maximize firm value.

(vii) Entrepreneurs choose e_t to maximize profit.

(viii) The real wage rate w_t clears the labor market.

(ix) Aggregate consumption C_t grows at rate $r_t - \rho$.

(x) Resource constraint is satisfied: $Y_t = C_t + \int_0^1 \sum_{i=1}^{N_{jt}} \chi z_{ijt}^{\phi} Y_t \, dj + \int_0^1 m_t \nu X_{kjt}^{\epsilon} Y_t \, dj + \psi e_t^2 Y_t + \sum_{\Theta} \sum_{i=1}^{N(\Theta)} \sum_{k \neq i} \sigma \int \mathbb{E}[\mathcal{A}_{ikt}(\Theta)] \mathcal{M}_{ikt}(\Theta) \mu_t(\Theta) \varphi Y_t dG(\varphi)$.

Growth Rate and Balanced Growth Path We can derive the growth rate of the economy at time t (g_t) as:

$$\begin{aligned} g_t \quad = \quad & -g_{\omega,t} + \sum \left[p_{lit}(\Theta) \ln(1+\lambda)\right] \mu_t(\Theta) \\ & + \sum_{\Theta} \sum_{i=1}^{N(\Theta)} \sum_{k \neq i} \sigma \mathbb{E}[\mathcal{A}_{ikt}(\Theta)] \mathcal{M}_{ikt}(\Theta) n_{likt}(\Theta) \ln(1+\lambda) \mu_t(\Theta) \\ & + \sum_{\Theta} \sum_{\Theta'} \left[f_t(\Theta') - f_t(\Theta)\right] p_t(\Theta, \Theta') \mu_t(\Theta) \end{aligned}$$

where $g_{\omega,t}$ is the growth rate of the relative wage, $\omega_t = \frac{w_t}{Y_t}$, $p_{lit}(\Theta)$ is the rate at which a leader innovates at time t, $n_{likt}(\Theta)$ is the step increase of the industry leader after a merger between firm i and k occurs at time t, the second term comes from the growth rate of the industry leaders, the third term comes from mergers, and the fourth term accounts for production reallocation as industries move between states.

In a balanced growth path with time-invariant distribution over Θ, $g_{\omega,t} = 0$, $\mu_t(\Theta) = \mu(\Theta)$ and:

$$\begin{aligned} g &= \sum \left[p_{li}(\Theta) \ln(1+\lambda)\right] \mu(\Theta) \\ &\quad + \sum_{\Theta} \sum_{i=1}^{N(\Theta)} \sum_{k \neq i} \sigma \mathbb{E}[\mathcal{A}_{ik}(\Theta)] \mathcal{M}_{ik}(\Theta) n_{lik}(\Theta) \ln(1+\lambda) \mu(\Theta) \end{aligned}$$

3 Estimation

In this section, we present the results of our estimation. The distribution from which the merger cost φ is drawn from, $G(\varphi)$, is assumed to be an exponential distribution with the parameter ξ; i.e. $G(\varphi) = 1 - e^{-\xi\varphi}$. The model has 17 parameters to be determined: $\lambda, \eta, \chi, \nu, \zeta, \phi, \epsilon, \tau, \psi, \gamma, \iota, \sigma, \xi, \rho, \alpha, \theta$, and κ. The consumer discount rate ρ is set to 0.04, which implies a real interest rate of 6% when the growth rate is 2%.[12] We assume both the acquirer and the target contribute equally to the productivity of the merged firm by setting $\alpha = 1 - \alpha = 0.5$. We set the bargaining power of an acquirer $\theta = 0.629$, which is the average share of merger surplus that accrues to acquirers estimated in Wang (2018). The parameter κ which determines the level of the HHI thresholds that the antitrust authorities use to investigate mergers is set to 1, which delivers a threshold of 0.15 for the industry HHI, and a threshold of 0.01 for the predicted change in industry HHI, which are consistent with the guidelines followed by the Department of Justice (DOJ) and the Federal Trade Commission (FTC) in the US. The remaining 13 parameters are structurally estimated following a simulated method of moments approach. We discuss the data moments that we use to discipline the parameter values, and provide the relevant data sources for each of these moments below:

1. **Average merger probability:** A superstar firm meets any of its competing superstar firms at the Poisson rate σ, which can then result in a successful merger if the merger creates a positive ex-ante surplus and if it is not obstructed by the antitrust authorities.

[12] We target a relatively high real interest rate to remain conservative. For instance, a lower real interest rate of 4% would halve the implied discount rate to $\rho = 0.02$. This would double the welfare contribution of the output growth rate relative to that from the initial consumption level, significantly amplify the dynamic welfare gains, and further strengthen our findings.

Table 1: Baseline Model Parameters and Target Moments

A. Parameter estimates

Parameter	*Description*	*Values*
σ	merger arrival rate	0.1728
ι	obstruction probability	0.0594
γ	synergy parameter	1.2115
ξ	merger cost parameter	14.8500
λ	innovation step size	0.3434
η	elasticity within industry	8.2707
χ	superstar cost scale	40.7334
ν	small firm cost scale	3.0890
ζ	competitive fringe ratio	0.5692
ϕ	superstar cost convexity	5.4040
ϵ	small firm cost convexity	3.0170
τ	exit rate	0.1151
ψ	entry cost scale	0.1628

B. Moments

Target moments	Data	Model
average merger probability	3.77%	3.83%
average obstruction rate	0.89%	0.88%
average merger gain	3.28%	3.51%
growth rate	2.20%	2.20%
R&D intensity	2.43%	2.03%
average markup	1.3498	1.3501
std. dev. markup	0.346	0.412
labor share	0.650	0.631
firm entry rate	0.115	0.115
β(innovation, relative sales)	0.629	1.062
top point (intra-industry)	0.505	0.435
average profitability	0.144	0.174
average leader relative quality	0.749	0.828
std. dev. leader relative quality	0.223	0.195

Notes: The estimation is done with the simulated method of moments. Panel A reports the estimated parameters. Panel B reports the simulated and actual moments.

To pin down the value of this parameter, we target the average annual merger probability for public firms in the US, which is 3.77%. This information is obtained from the SDC Platinum dataset by Refinitiv.

2. **Average obstruction rate:** A merger transaction between two companies can be obstructed by the antitrust authorities. In the model, a merger transaction is scrutinized by the authorities if the HHI-based guidelines require an investigation to be conducted. Conditional on an investigation, the probability of obstruction is given by ι. To pin down the value of this parameter, we target the fraction of obstructed merger transactions among all merger transactions that were reported to the DOJ and the FTC. According to the Hart-Scott-Rodino Annual Report for FY 2018, 18 out of 2,028 merger transactions were obstructed, which delivers a target of $18/2028 = 0.89\%$. We require our model to match this average obstruction probability among all superstar mergers.

3. **Average merger gain:** In the model, the expected productivity of a merged firm is a Cobb-Douglas aggregate of the productivities of the target and the acquirer. The scale parameter of this function, γ, determines the gains from synergy due to the cost reductions that can be achieved through M&A. To discipline the value of this parameter, we target the average merger gains in the US. This information is obtained from the SDC Platinum Dataset by Refinitiv. In particular, we use the average combined announcement returns of public-to-public mergers, which is 3.28%.

4. **Growth rate:** The targeted growth rate is obtained as the geometric average of real GDP per capita growth over our time period available from the US Bureau of Economic Analysis.

5. **R&D intensity:** Aggregate R&D intensity is measured as the ratio of total R&D expenditures to GDP obtained from the National Science Foundation.

6. **Level and dispersion of markups:** The average markup and its standard deviation are targeted to those reported in De Loecker, Eeckhout, and Unger (2020).

7. **Labor share:** Time series for labor and capital shares are respectively obtained from Karabarbounis and Neiman (2013) and Barkai (2016) from which we compute averages over our time period. Since our model does not feature capital, the labor share that our model delivers is adjusted for comparability by multiplying it by one minus the capital share.[13]

[13]See the extension with endogenous capital accumulation in Cavenaile, Celik, and Tian (2019) to see why this adjustment is appropriate.

8. **Firm entry rate:** The entry rate of new businesses is retrieved from the Business Dynamics Statistics database. It corresponds to the entry of small firms in our model.

9. **Relationship between firm innovation and relative sales:** The relationship between firm innovation and market shares is key to determine the growth and welfare implications of mergers and antitrust policy. We, therefore, require our model to match the inverted-U relationship between innovation and market shares observed in the data. In particular, we target the coefficients reported in Cavenaile, Celik, and Tian (2019) for the linear and quadratic terms of a regression of (standardized) innovation (average patent citations) on market shares. We perform the same regression in the model using the standardized Poisson arrival rate of productivity improvement as the measure of innovation.

10. **Average profitability:** We target the average profitability ratio obtained from Compustat as the ratio of operating income before depreciation and sales. In the model, it is measured as the average ratio of static profit flow after R&D expenses and sales of superstar firms.

11. **Level and dispersion of leader quality:** To proxy quality in the data, we first compute the stock of past patent citations. We then measure the relative quality of the leader as the ratio of its quality to the sum of qualities of the top four firms in the same industry (four-digit SIC). We target the average and standard deviations of this measure of relative leader quality in the model, in which relative qualities are known.

Panel A of Table 1 reports the values of the parameters, whereas Panel B provides an overview of the values of the targeted moments in the data and the estimated model. The model tightly matches the 14 data moments.

4 Quantitative Results

In this section, we use our quantitative model to first examine the properties of the estimated equilibrium, and demonstrate the model-implied relationship between innovation and competition, as well as M&A activity and market concentration. Next, we conduct a counterfactual exercise where we shut down antitrust enforcement completely to assess the macroeconomic impact of the existing antitrust policies regarding M&A. We then conduct two counterfactual exercises in which we impose stronger antitrust enforcement through (1) lower HHI thresholds for investigation and (2) higher obstruction rate conditional on investigation. We decompose the welfare effects of these counterfactual experiments, which reveals that the dynamic welfare effects of antitrust enforcement are an order of magnitude stronger than the static effects which the existing literature mainly focuses on. Finally, we investigate which mergers in our model are "anticompetitive acquisitions" – acquisitions that would go through even if there were no synergies – and assess to what extent the existing guidelines adopted by the antitrust authorities in the US effectively target this kind of mergers.

4.1 Innovation Policy Functions

Figure 1 displays the optimal innovation policy functions followed in the estimated equilibrium for industries with two (left panel) and three superstar firms (right panel). The left panel of Figure 1 depicts the innovation policy of a firm in an industry with two superstar firms. The relevant state variable is by how many steps a firm is ahead of its competitor (negative values indicate that the firm is lagging behind its competitor). In a two-superstar industry, we can see that incentives to innovate are the highest when superstars are close to being neck-and-neck. A firm's innovation rate is increasing until it lags behind its single competitor by one step and then decreasing as it increases its lead. As a result, total innovation of two-superstar industries is the highest for industries where superstar firms are close to each other in terms of productivity (neck-and-neck and one step difference).

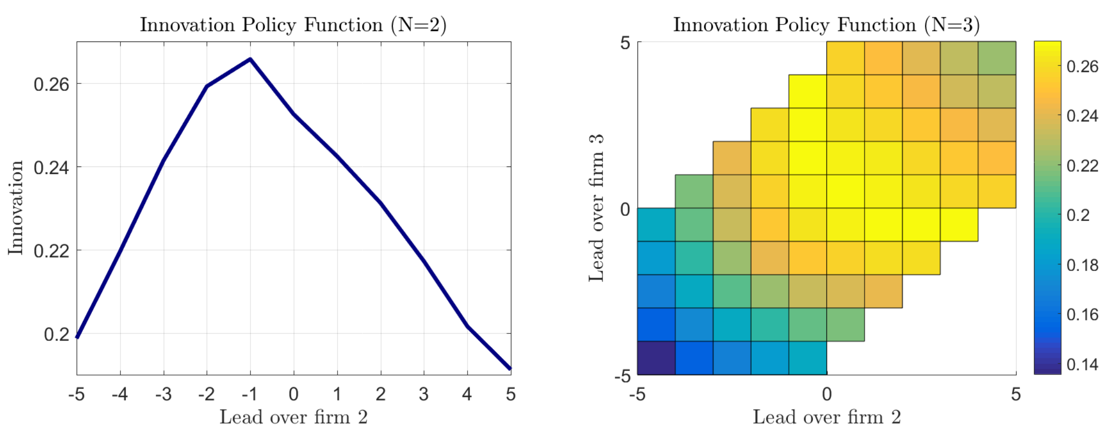

Figure 1: Innovation Policy Functions

The right panel of Figure 1 shows the innovation policy of a firm in a three-superstar industry as a function of its productivity lead over its two competitors. Given our assumption that productivity lead cannot exceed $\bar{n}$, some states are impossible in the model and correspond to the empty regions at the bottom right and top left corners of the figure. We can notice a similar pattern to the two-superstar case with the incentives to innovate being the highest when all firms are close to each other in terms of productivity.

4.2 Innovation and Competition

As our objective in this paper is to quantify the welfare effect of antitrust policy when dynamic considerations about innovation are taken into account, it is crucial that our model is able to reproduce the empirically observed relationship between innovation and competition. From that perspective, our model offers a framework which is able to endogenously replicate the observed inverted-U shape relationship between innovation and competition both across and within industries (see for instance Aghion, Bloom, Blundell, Griffith, and Howitt (2005) and Cavenaile, Celik, and Tian (2019) for empirical evidence). In particular, our estimated model delivers an inverted-U relationship between superstar innovation activity and their market shares within their industry as well as between total innovation within an industry and measures of market concentration such as the Herfindahl-Hirschman Index. The two panels of Figure B1 depict the model-implied firm-level relationship of innovation and R&D with market shares respectively, whereas Figure B2 displays the industry-level relationship between innovation and HHI. Consistency along these dimensions is crucial for estimating the effect of antitrust policies on welfare since mergers directly affect market concentration. On the other hand, merger opportunities also affect the incentives to innovate by superstar firms as well as by small firms. Our model can also generate realistic HHI numbers, which is a feature missing in endogenous growth models with Bertrand competition and homogeneous goods – the dominant paradigm in this literature. These features allow us to directly map our model to the actual HHI-based rules followed by antitrust authorities when reviewing merger transactions and to offer a quantitative evaluation of the dynamic growth and welfare effects of antitrust policies. Owing to these features, to our knowledge, our model is the first general equilibrium model with endogenous growth and heterogeneous markups which makes a dynamic quantitative investigation of the welfare effects of antitrust possible.

4.3 M&A Activity and Market Concentration

Another interesting dimension to consider is the relationship between the intensity of M&A activity and market concentration. In the model, the decision to merge depends both on the productivities of the two firms, as well as on the number and relative productivities of their competitors. This means the decision to merge depends on the industry state Θ. In addition, even if two firms decide to merge together, their merger can be investigated by the antitrust authorities, and potentially obstructed through a challenge. The antitrust authorities in our model mimic the guidelines announced by the DOJ and the FTC in the US, and therefore there is intervention only when the industry's HHI is projected to be above 0.15, and the merger would increase HHI by more than 1%. All of these effects create a significant amount of heterogeneity in the intensity of observed M&A activity across different industries.

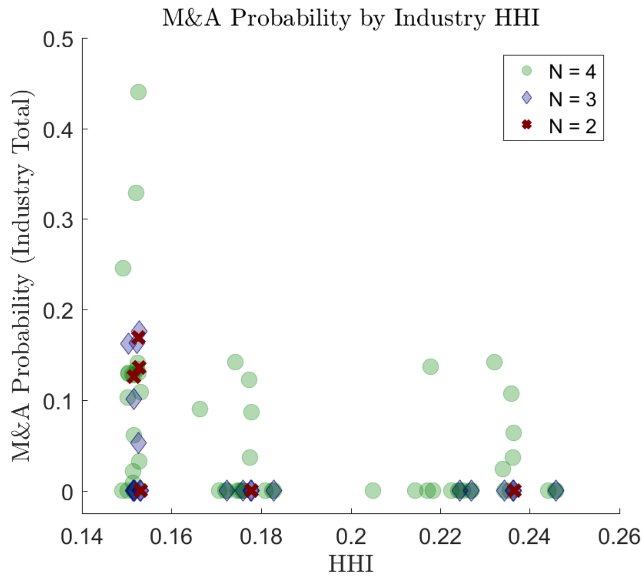

Figure 2: M&A Probability by Industry HHI

Figure 2 displays the relationship between M&A intensity and market concentration. The annual probability of M&A by any two firms in a given industry is shown on the vertical axis. Market concentration as captured by HHI is shown on the horizontal axis. Each dot represents one of the 83 unique industry states Θ, and the color depends on the number of superstar firms present in the particular industry state. Overall, one can see a decreasing pattern: M&A activity is highest in less concentrated industries. Both incentives and antitrust policy play a role here: The antitrust policy only obstructs mergers when the HHI is projected to go above 0.15, so mechanically, industries with a low HHI are less affected. On the incentive side, from the firms' point of view, consolidation in less concentrated industries yields a higher surplus on average.

In addition to the overall negative relationship, we also observe that mergers are most common in industries with four superstar firms. However, M&A still takes place in industries with two and three superstar firms. In industries with two superstar firms, the firms merge to become a single dominant firm only when the quality difference is considerably high: i.e. when the step size difference is $n \in \{\bar{n}, \bar{n}-1, \bar{n}-2\}$. This means that duopolies[14] do not turn into monopolies[15] when the competitors are close in productivity to each other. A merger happens only when the leader meets a newly minted superstar firm that did not have sufficient time to improve its productivity, or when a previously productive competitor fails to keep up

[14] Here we use duopoly to refer to the existence of two superstar firms (as opposed to two firms) since there is always a mass of small firms that also compete with the superstars.

[15] Again, this should be understood as a dominant firm rather than a literal monopoly.

with and lags too much behind the leader. The resulting transition rate from duopolies to monopolies is of particular interest, since superstars stop all innovation if they are left alone. We will see the growth and welfare implications of this observation in the counterfactual experiment with stronger antitrust enforcement.

4.4 Social Welfare

In the following sections, we will compute social welfare in counterfactual economies and compare the results to the welfare in the estimated equilibrium. In a BGP equilibrium, two components are required to compute welfare: the growth rate of consumption g, and the initial consumption level C_0. This, in turn, requires us to compute initial output Y_0, aggregate spending on R&D, new business creation, as well as merger costs. The level of initial output Y_0 is given by:

$$\ln(Y_0) = \int_0^1 \ln q_{j0}^{\text{leader}} \, dj + \ln \zeta - \ln \omega + \sum f(\Theta)\mu(\Theta) \tag{36}$$

All terms are time-invariant except for the average log productivity level of the industry leaders at time 0, given by $\int_0^1 \ln q_{j0}^{\text{leader}} dj$. When comparing welfare across economies, we fix this term to be equal to zero in all economies without loss of generality.[16] Next, initial consumption C_0 is given by

$$\begin{aligned} C_0 = Y_0 \frac{C_0}{Y_0} \quad &= \quad Y_0 \Bigg(1 - \int_0^1 \sum_{i=1}^{N_{j0}} \chi z_{ij0}^{\phi} \, dj - \int_0^1 m_0 \nu X_{kj0}^{\epsilon} \, dj - \psi e_0^2 \\ &\quad - \sum_{\Theta} \sum_{i=1}^{N(\Theta)} \sum_{k \neq i} \int \sigma \mathbb{E}[\mathcal{A}_{ik0}(\Theta)] \mathcal{M}_{ik0}(\Theta) \mu_0(\Theta) \varphi dG(\varphi) \Bigg) \end{aligned} \tag{37}$$

where the second factor is the share of output left for consumption after R&D, new business creation, and merger costs are subtracted. Then, the welfare of the representative household in a BGP equilibrium can be calculated as:

$$W = \int_0^\infty e^{-\rho t} \ln(C_t) dt = \frac{ln(C_0)}{\rho} + \frac{g}{\rho^2} \tag{38}$$

The model allows for a closed-form decomposition of changes in welfare across two economies as follows:

$$\Delta W = \frac{1}{\rho} \left[\Delta \ln \zeta - \Delta \ln \omega + \Delta \sum f(\Theta)\mu(\Theta) + \Delta \ln \left(\frac{C}{Y} \right) \right] + \frac{\Delta g}{\rho^2} \tag{39}$$

[16] In other words, we keep the initial frontier technology level the same across counterfactual economies.

For two economies A and B, we can define a consumption equivalent welfare measure (ϖ) which corresponds to the percentage increase in lifetime consumption that an agent in economy A would need to be indifferent between being in economy A and B:

$$W_B = \frac{\ln(C_0^A(1+\varpi))}{\rho} + \frac{g^A}{\rho^2} \tag{40}$$

Solving for ϖ, we get:

$$\varpi = \exp\left(\left(W_B - \frac{g^A}{\rho^2}\right)\rho - \ln(C_0^A)\right) - 1 \tag{41}$$

4.5 The Impact of Shutting Down Antitrust Enforcement

In the past decade, several industries in the US have undergone considerable consolidation as a result of increased M&A activity. From 2009 to 2018, the number of transactions that were reported to the Federal Trade Commission (FTC) and the Department of Justice (DOJ) under the Hart-Scott-Rodino Antitrust Improvements Act increased steadily from 684 to 2,028 per year. At the same time, the percentage of transactions in which either the FTC or the DOJ issued a second request for information dropped from 4.5% to 2.2%. In 2018, out of the 45 such cases, 39 mergers were challenged, but only 13 deals were abandoned or restructured, and 5 cases resulted in litigation, corresponding to an obstruction rate of 40% conditional on second request issuance. In contrast, in addition to the higher second request issuance rate in 2009, the conditional obstruction rate was also higher at 52%. In sum, the percentage of obstructed merger transactions was three times higher in 2009 compared to 2018, and those that were challenged but not blocked were successfully settled in accordance with the requests by the two institutions.[17]

In light of the observed increase in the leniency of (de facto) antitrust enforcement in the US, a natural question to ask is whether the existing antitrust laws and their enforcement are sufficient to safeguard the interests of consumers, promote economic growth, and maximize social welfare. In our first counterfactual exercise, we assess the dynamic effects of the existing antitrust enforcement in 2018 on the macroeconomy by shutting down antitrust enforcement altogether.

To conduct this experiment, we set the value of the parameter that governs the obstruction probability conditional on investigation, ι, to zero. Consequently, no merger attempts by firms are obstructed regardless of how high market concentration is, or the magnitude of its predicted change. The results of this experiment are displayed in Table 2.

[17] Refer to Kwoka (2014) and Gutiérrez and Philippon (2018) and the references therein for more information on the increasing leniency of antitrust enforcement in the US.

Table 2: The Aggregate Impact of Shutting Down Antitrust

	Benchmark	No Antitrust	% change
average merger probability	3.826%	3.848%	0.56%
average obstruction rate	0.877%	0.000%	-100.00%
average merger gain	3.506%	3.498%	-0.21%
growth rate	2.196%	2.176%	-0.88%
R&D intensity	2.025%	2.018%	-0.39%
average markup	1.350	1.350	-0.01%
std. dev. markup	0.412	0.413	0.02%
labor share	0.631	0.632	0.01%
entry rate	0.115	0.115	0.00%
β(innovation, relative sales)	1.062	1.062	-0.05%
top point (intra-industry)	0.435	0.435	0.00%
average profitability	0.174	0.174	0.01%
average leader relative quality	0.828	0.829	0.09%
std. dev. leader relative quality	0.195	0.195	-0.11%
superstar innovation	0.264	0.263	-0.31%
small firm innovation	0.090	0.090	0.38%
output share of superstars	0.429	0.429	-0.07%
average superstars per industry	1.688	1.686	-0.09%
mass of small firms	1.000	1.002	0.24%
initial output	0.762	0.762	-0.02%
C.E. welfare change	-	-0.491%	-

The first fourteen rows of Table 2 are reserved for the fourteen macroeconomic quantities that we used in the estimation to discipline the model parameters, whereas the last seven rows report model-specific quantities that are the most important for understanding the impact on the level and growth rate of aggregate output and the resultant changes in social welfare. The first column presents the quantities from the estimated equilibrium. The second column presents the quantities from the equilibrium of the counterfactual economy with no antitrust enforcement. The last column displays the percentage change in the counterfactual economy compared to the baseline for ease of inspection.

As a direct effect of shutting down antitrust enforcement, the average annual merger probability in the economy increases by 0.56%. This very modest increase despite the complete shutdown of antitrust enforcement is due to the extremely permissive antitrust policy that was in effect in the US in 2018. The average merger gain, which measures the average surplus achieved in a given merger compared to the combined value of the two firms before merger, declines by 0.21% of its value. In sum, shutting down antitrust enforcement does not create a tremendous increase in the frequency of M&A, or affect its profitability conditional on realization by much.

How does static efficiency change? First, we observe that the average number of superstars per industry declines slightly by 0.1%. This is mostly due to a shift from two superstar industries to single superstar industries. As a consequence of the changes to the industry state distribution $\mu(\Theta)$, the output share of superstars declines slightly by 0.07%, which hurts allocative efficiency as the elimination of superstars causes production to be reallocated to small firms with lower productivity. This leads to a very slight increase in the labor share at 0.01%. Likewise, since superstar firms have positive markups compared to the zero markups of the small firms, the average markup is also slightly decreased, whereas the dispersion of markups goes up.[18] The total effect of these changes is a 0.02% decline in initial output.

In a static model, the slight 0.02% decline in static efficiency would be the end of the story, and one could therefore conclude that the welfare gains from the existing antitrust policies are extremely small, yet positive. Using our model, we find that the dynamic effects of antitrust policy are an order of magnitude more important compared to the static effects for social welfare. Shutting down antitrust enforcement results in a 0.31% decline in superstar innovation. Combined with a shift in M&A activity towards less synergistic mergers, this leads to a 0.88% decline in the aggregate growth rate compared to its value. Unlike the trivial decline in static efficiency, the decline in the growth rate has a larger welfare impact. Combined with the static efficiency losses, the welfare of the representative consumer in this hypothetical economy is 0.49% lower compared to the benchmark in consumption-equivalent terms. Having observed that the welfare impact of the existing antitrust enforcement in 2018 is positive yet modest, we investigate the effects of stronger antitrust policy next.

4.6 The Impact of Stronger Antitrust Enforcement

As mentioned before, the antitrust authorities in the model mimic the guidelines announced by the DOJ and the FTC. There are two parameters that govern how strict antitrust enforcement is: the parameter κ which governs the levels of the HHI thresholds that the antitrust authorities use as guidelines to investigate proposed merger transactions, and the obstruction probability conditional on investigation, ι. Decreasing the value of κ leads the antitrust authorities to investigate a broader set of merger transactions, whereas increasing the value of ι increases obstruction rate conditional on investigation.

[18] Konings, Van Cayseele, and Warzynski (2001) and Kee and Hoekman (2007) find very modest and insignificant effects of the introduction of competition (antitrust) laws on markups in both developed and developing countries. This is consistent with the quite muted response of markups to changes in antitrust enforcement in our model.

To assess the impact of stronger antitrust enforcement, we conduct two exercises. In the first exercise, we decrease the value of κ by 10% of its value. As a result of this change, the antitrust authorities investigate mergers when the industry HHI is above 0.135 (instead of 0.150) and the increase in industry HHI as a result of the deal is estimated to be above 0.009 (instead of 0.010). In the second exercise, we do not change κ, but increase the obstruction probability ι to five times its estimated value. Both experiments yield the same increase in the average obstruction rate, but with differing implications for macroeconomic aggregates, growth, and welfare.

Table 3: The Aggregate Impact of Stronger Antitrust Enforcement

	Benchmark	Lower HHI Thresholds	% change	Higher Obstruction Rate	% change
average merger probability	3.826%	3.739%	-2.28%	3.727%	-2.58%
average obstruction rate	0.877%	4.868%	455.08%	4.870%	455.22%
average merger gain	3.506%	3.576%	2.01%	3.538%	0.94%
growth rate	2.196%	2.273%	3.54%	2.284%	4.03%
R&D intensity	2.025%	2.037%	0.55%	2.061%	1.77%
average markup	1.350	1.350	0.01%	1.351	0.03%
std. dev. markup	0.412	0.412	-0.02%	0.412	-0.09%
labor share	0.631	0.631	-0.01%	0.631	-0.04%
entry rate	0.115	0.115	0.00%	0.115	0.00%
β(innovation, relative sales)	1.062	1.058	-0.36%	1.064	0.19%
top point (intra-industry)	0.435	0.436	0.02%	0.436	0.02%
average profitability	0.174	0.174	-0.04%	0.174	-0.04%
average leader relative quality	0.828	0.827	-0.16%	0.825	-0.40%
std. dev. leader relative quality	0.195	0.195	0.04%	0.196	0.49%
superstar innovation	0.264	0.266	0.75%	0.268	1.44%
small firm innovation	0.090	0.089	-0.76%	0.089	-1.73%
output share of superstars	0.429	0.430	0.07%	0.431	0.32%
average superstars per industry	1.688	1.692	0.27%	1.695	0.43%
mass of small firms	1.000	0.995	-0.53%	0.989	-1.11%
initial output	0.762	0.762	0.02%	0.762	0.08%
C.E. welfare change	-	1.972%	-	2.287%	-

The results of both experiments are presented in Table 3. The values in the estimated economy are shown in column 1 for reference. Column 2 presents the results from the first experiment where HHI thresholds for investigation are reduced, whereas column 4 presents the results from the second experiment with higher obstruction rate conditional on investigation. Columns 3 and 5 display the percentage changes compared to the benchmark.

In both experiments, the average obstruction rate is increased by 4.55 times its original value. While this seems like a tremendous increase, the counterfactual value is lower than two times the obstruction rate in 2009, and owes mostly to the very lenient antitrust enforcement in 2018. Despite the seemingly huge increase, the average annual merger probability in the economy falls by only 2.28% of its value in the first experiment, and 2.58% in the second experiment. Average merger gain increases by 2.01% with lower HHI thresholds, but only 0.94% with a higher obstruction rate. Overall, the 4.5-fold increase in the obstruction rate does not reduce M&A activity considerably, and the observed merger gains in mergers that go through are slightly higher.

As in the shutdown counterfactual, we start with an analysis of the effects of the two experiments on static efficiency. The average number of superstars per industry goes up in both experiments, but increasing the obstruction rate yields a larger and more targeted increase. In particular, increasing the obstruction rate lowers the fraction of single superstar industries moreso than lowering the HHI thresholds. Consequently, the increase in the output share of superstars in the second experiment is nearly four times larger than in the first experiment. This leads to a static efficiency gain that is four times as large at 0.08%, as opposed to 0.02% achieved with lower HHI thresholds. In alignment with the discussion in the previous section, the rise in allocative efficiency comes together with a very slight decrease in the labor share, and a slight increase in the average markup.

Once again, the dynamic effects of antitrust policy are found to be an order of magnitude more important than the static gains in allocative efficiency. Stronger antitrust enforcement has heterogeneous implications for the innovation conducted by small versus large firms, and the magnitudes are also quite different across the two experiments. Table 3 displays the heterogeneity between superstars and small firms as a whole, whereas Table 4 presents the heterogeneous responses within the two groups; i.e. how total superstar innovation and total small firm innovation change compared to the baseline, conditional on the number of superstar firms in each industry.

Table 4: Innovation by the Number of Superstar Firms in the Industry

	Total Superstar Innovation				Total Small Firm Innovation			
	N=1	N=2	N=3	N=4	N=1	N=2	N=3	N=4
Baseline	0.0000	0.1490	0.0915	0.0235	0.0573	0.0252	0.0077	0.0000
Lower HHI Thresholds	0.0000	0.1506	0.0920	0.0235	0.0565	0.0253	0.0077	0.0000
% change	-	1.029%	0.504%	-0.056%	-1.354%	0.382%	-0.082%	-
Higher Obstruction Rate	0.0000	0.1522	0.0924	0.0233	0.0559	0.0251	0.0076	0.0000
% change	-	2.155%	0.885%	-0.894%	-2.409%	-0.349%	-1.180%	-

First, we focus on small firm innovation. On average, the value of becoming a superstar firm goes down for small firms, as the option value derived from the opportunities in the M&A market dwindle as a result of stronger antitrust enforcement. Consequently, the value of small firms declines, which reduces the incentives of the entrepreneurs to create new businesses.

This results in a decline in the equilibrium mass of small firms by 0.53% and 1.11% in the first and second experiments, respectively. Combined with a lower innovation intensity chosen by small firms, total small firm innovation goes down by 0.76% of its value with lower HHI thresholds, and by 1.73% with the higher obstruction rate, indicating a lower emergence rate of new superstars in both experiments. In other words, stronger antitrust policy reduces business dynamism through its negative impact on the option value of small firms derived from M&A opportunities that are now more likely to be obstructed.

Next, we consider innovation by superstar firms. The decline in the frequency of single firm industries results in higher dynamic competition across superstar firms. When faced with peer competitors with similar productivities, superstars increase their innovation intensity as the escape-competition effect dominates the Schumpeterian creative destruction effect of lower profits. This is particularly true for industries with two superstars. Consequently, we observe a 0.75% increase in superstar innovation with lower HHI thresholds, and a 1.44% increase with a higher obstruction rate.

Combining the dynamic effects of innovation by small firms and superstars, as well as the synergy gains from successful mergers, we calculate that the growth rate of aggregate output increases by 3.54% of its value in the first experiment, and 4.03% in the second experiment. In addition, the increased growth in both experiments is the result of rather modest increases in the aggregate R&D expenditure share at 0.55% and 1.77% of its value. Combined with the more modest increases in allocative efficiency discussed earlier, stronger antitrust enforcement achieved through lowering HHI thresholds is calculated to increase social welfare by 1.98% in consumption-equivalent terms in the long run, whereas the gain is even larger at 2.29% with the more targeted higher obstruction rate experiment. Given the very limited impact on overall M&A activity, these results showcase that higher antitrust enforcement achieved through both methods could yield disproportionately large gains in welfare, since the dynamic effects on superstar innovation (through more intense dynamic competition in innovation among peer superstar firms) is found to be quite substantial despite the low rate of obstruction (4.87% among all merger transactions between superstar firms).

4.7 Decomposition of the Dynamic Welfare Effects and Distributional Consequences

To better understand the static vs. dynamic efficiency gains from the counterfactual experiments, it is useful to decompose the change in welfare to its constituent parts using equation (39). This is done in the first panel of Table 5. The first three rows depict the components that change initial output, Y_0. The relative productivity of small firms in the competitive fringe does not change, as the parameter ζ is held constant in all experiments. The relative wage ω affects initial output negatively, as higher wages result in lower labor demand by firms. The output of superstar firms term is positively associated with the average number of superstars per industry. The total effect on initial output is negative when antitrust is shut down, and positive when antitrust enforcement is strengthened. However, the welfare impact of the change in initial output remains limited in all experiments, and the largest welfare change is observed in the experiment with higher obstruction rate at 0.08% in consumption-equivalent terms.

Table 5: Decomposition of the Dynamic Welfare Effects and Distributional Consequences

	No Antitrust		Lower HHI Thresholds		Higher Obstruction Rate	
	ΔW	CEWC	ΔW	CEWC	ΔW	CEWC
competitive fringe productivity	0.0000	0.0000%	0.0000	0.0000%	0.0000	0.0000%
relative wage	-0.0024	-0.0094%	0.0025	0.0098%	0.0108	0.0432%
output of superstar firms	-0.0021	-0.0084%	0.0022	0.0087%	0.0096	0.0384%
consumption/output	0.0017	0.0069%	-0.0022	-0.0090%	-0.0080	-0.0319%
output growth	-0.1203	-0.4800%	0.4856	1.9613%	0.5529	2.2363%
total, rep. household	-0.1230	-0.4908%	0.4880	1.9711%	0.5654	2.2872%
worker consumption/output	0.0024	0.0094%	-0.0025	-0.0098%	-0.0108	-0.0432%
initial output	-0.0045	-0.0178%	0.0046	0.0186%	0.0204	0.0816%
output growth	-0.1203	-0.4800%	0.4856	1.9613%	0.5529	2.2363%
total, worker	-0.1224	-0.4884%	0.4878	1.9702%	0.5625	2.2756%
capitalist consumption/output	-0.0013	-0.0051%	-0.0001	-0.0005%	0.0059	0.0235%
initial output	-0.0045	-0.0178%	0.0046	0.0186%	0.0204	0.0816%
output growth	-0.1203	-0.4800%	0.4856	1.9613%	0.5529	2.2363%
total, capitalist	-0.1260	-0.5028%	0.4901	1.9798%	0.5792	2.3438%

The fourth and fifth rows present the change in welfare due to the dynamic responses of the model. The consumption to output ratio, as shown in equation (37), is decreasing in total R&D expenditures by small and large firms, as well as new business creation and merger costs. The total R&D expenditure of superstar firms is the dominant term among the four. Higher spending on these dynamic investment channels reduces the consumption to output ratio and consequently welfare; however, the dynamic gains due to increased aggregate productivity growth easily overshadow its effects. This is shown in the fifth row. In the first experiment with no antitrust, nearly 98% of the 0.49% loss in welfare is due to the decline in growth. Likewise, the 1.97% and 2.29% gains in welfare in the second and third experiments mostly owe to the dynamic gains from higher growth rather than higher static efficiency. In all experiments, the combined welfare impact of the dynamic components is more than 25 times larger than that of the static components.

How to interpret these findings? Although our results for the relative magnitude of welfare implications are (inescapably and naturally) model-dependent, they suggest that the dynamic consequences of antitrust policy can be an order of magnitude more important than the consequences for static efficiency. The current antitrust policy that is being enforced by the DOJ and the FTC in the US is openly contingent on predicted changes in market concentration calculated using static models. In addition, the stated goal of the antitrust authorities is not to maximize static welfare, but consumer surplus (i.e. producer surplus is ignored). Our results suggest that the long-run impact on the industrial structure (the distribution of industry-states $\mu(\Theta)$ in the model) and the consequent changes in innovation policy and aggregate productivity growth should receive much higher consideration in the decisions to challenge merger transactions if the goal of the antitrust policy is to maximize social welfare.

Another interesting question to ask is how the gains from changes in antitrust policy accrue to the agents in the economy. In our previous calculations, we focused solely on the welfare of the representative consumer. However, given the high degree of wealth inequality documented in the US, such an analysis might not be sufficient to paint a complete picture. To investigate the distributional consequences of the three experiments, we separate the representative consumer into two hypothetical agents: (1) a pure worker, who collects all labor income, but cannot save or dissave, and (2) a pure capitalist, who owns all the assets in the economy, including the revenue streams from new business creation. The second and third panels of Table 5 decompose the welfare of these two hypothetical agents.

Both agents' welfare is affected by initial output and output growth; therefore, the gains in static and dynamic efficiency influence the welfare of both consumers similarly. The consumption to output ratio of the worker is equal to the relative wage ω, which goes up in the no antitrust scenario, and down with stronger antitrust enforcement. The consumption to output ratio of the capitalist depends on the (normalized) value of all firms, which goes down in the no antitrust experiment, stays nearly unchanged with lower HHI thresholds, and increases with a higher obstruction rate. Despite these differences, the consumption-equivalent welfare changes of both agents are largely aligned with each other, since the dynamic effect from productivity growth dominates all welfare effects from changes arising from the consumption to output ratios. In other words, we find both workers and capitalists alike benefit from higher antitrust enforcement.

The finding that capitalists also benefit from higher antitrust enforcement might seem counterintuitive at first. However, the hypothetical capitalist in our example is one that owns a perfectly diversified portfolio of all assets in the economy. If we focus on particular asset types, the situation changes. Table 6 decomposes the impact of the three experiments on

Table 6: Decomposing the Impact on Asset Values

	No Antitrust	Lower HHI Thresholds	Higher Obstruction Rate
% change in the value of superstar firms	-0.0160%	0.0230%	0.0732%
% change in the value of small firms	0.4847%	-1.0591%	-2.2122%
% change in the value of entrepreneurs	0.4851%	-1.0591%	-2.2121%
% change in the value of all assets	-0.0051%	-0.0005%	0.0235%

the values of different asset types. Shutting down antitrust reduces the value of superstar firms, but increases the value of small firms and entrepreneurs. Similarly, increasing antitrust enforcement increases the value of superstar firms, but causes a significant decline in the value of small firms and entrepreneurs.

Furthermore, there are heterogeneous responses even within these asset classes. There are both winners and losers among superstar firms, and the exact effect depends on how close they (or their competitors) are to a state in which M&A is both likely to happen, and subject to potential obstruction in the benchmark economy. Firms that are well-positioned to benefit from unobstructed merger transactions would favor no enforcement, whereas firms that face the risk of consolidation among their competitors would not. Despite the differences, taken as a whole, superstar firms are negatively affected by lower antitrust enforcement. However, capitalists with non-diversified portfolios might still favor lower enforcement depending on the exact composition of the assets they own.

4.8 Anticompetitive Acquisitions and Antitrust Enforcement

In our model, mergers among firms can lower or increase welfare. Socially desirable mergers might occur due to the potential synergy embedded in the merger technology described in equation (8). At the same time, firms can also engage in horizontal mergers to reduce or eliminate competition, due to both static (improving their current market share) and dynamic (lowering the risk of being surpassed in the future) reasons. Such mergers would net a positive surplus to the merging firms, but reduce overall welfare. Recent work attempts to identify such "killer" or "anticompetitive acquisitions" where the goal of the acquiring firm is to preempt future competition from innovative targets (Cunningham, Ederer, and Ma (2020), Wollmann (2019)). One question worth investigating is whether the existing guidelines followed by the antitrust authorities are successful in targeting such "anticompetitive acquisitions".

To answer this question, we conduct a hypothetical thought experiment for each possible merger scenario in our model. We call an acquisition an "anticompetitive acquisition" if the merger deal would still yield a positive total surplus if (1) the target firm were to be completely liquidated, and (2) the acquirer firm would continue its operations with its productivity unchanged. This thought experiment therefore identifies mergers that would still go through if there were no synergy gains – i.e. eliminating the competition would be a sufficient reason by itself for the acquisition.[19] With this definition, we investigate the prevalence of such acquisitions as a function of the industry-states, and measure whether they are scrutinized according to the existing HHI-based guidelines in the benchmark economy.

We find that only mergers in industries with two superstars meet our criteria to be classified as anticompetitive acquisitions. An acquisition in such industries converts them to a single-superstar industry in which the remaining superstar need not invest in any innovation until another superstar emerges as a result of small firm innovation. As discussed before, acquisitions in two superstar industries are only profitable when the second superstar is much less productive (and therefore smaller) than the industry leader. Consequently, anticompetitive acquisitions target either newly-minted superstars, or those that have shrunk considerably over time due to continued lack of success in innovation. At the date of acquisition, product market competition from such targets is trivial, but the potential threat from their future innovation is not. Therefore, the industry leader finds it optimal to acquire them due to dynamic considerations, and eliminate competition preemptively.

Focusing on the efficacy of the HHI-based rules to target such anticompetitive acquisitions yields mixed results. The fraction of anticompetitive acquisitions that are investigated is only 16.6%. The largest such acquisitions meet the HHI-based criteria, and are obstructed at the rate ι. However, the overwhelming majority of anticompetitive acquisitions stay under the radar, since the predicted change in HHI remains below the 1% threshold due to the small size of the targets.

The situation is the opposite in industries with more than two superstars. In three and four superstar industries, none of the acquisitions are classified as anticompetitive acquisitions according to our definition. Despite this fact, 4.08% of the acquisitions in three superstar industries, and 1.18% of those in four superstar industries are investigated.

While the lower investigation rate of non-anticompetitive acquisitions points to some degree of success of the HHI-based rules in targeting anticompetitive acquisitions moreso than the rest, our analysis suggests the existence of considerably large type-I and type-II errors. From a less model-dependent perspective, the primary weakness seems to be the inability to capture merger transactions that involve currently small, but potentially very innovative targets. If acquirers can assess the future potential of innovative targets before the targets ramp up their production and market share, an acquisition is possible without triggering the scrutiny of the antitrust authorities. Ignoring such dynamic considerations may therefore

[19]Note that our definition differs from that in the literature in that there might still be synergy gains from these mergers. The acquirers need not discontinue the products or innovation projects of the target.

be suboptimal. While figuring out better rules-of-thumb remains beyond the scope of our current study, our model suggests the relative value of the target firm might contain useful information insofar as it captures the future growth prospects of the company.

5 Model Extensions

In this section, we present two extensions to our baseline model: antitrust decision anticipation, and elastic labor supply.

5.1 Antitrust Decision Anticipation

It is possible that firms in the real world have more information regarding the potential outcome of a merger transaction proposal. If firms can anticipate that their merger transaction will be blocked by the authorities with reasonable accuracy, they might be dissuaded from applying for a merger in the first place. In such a setting, the empirically observed probability of merger obstruction would be lower than the (unobserved) true merger obstruction rate: some additional potential mergers are obstructed, but we never observe them in the data since the firms do not apply for a merger in the first place, given that they can anticipate the negative outcome in advance. If this is the case, there can be many more potential mergers that are obstructed under the current antitrust regime that we never observe, and the obstructions that we observe might just be “the tip of the iceberg”.

In Section A.2 of the appendix, we develop an extended model in which we allow firms to anticipate the decision of the antitrust authorities with some probability before they apply for a merger. Given this information, firms can choose not to apply for a merger in the first place, knowing that the deal will be rejected. This generates a wedge between the observed merger obstruction rate, and the unobserved true merger obstruction rate.

We re-estimate this extended model under different values for the anticipation probability, and repeat the no antitrust enforcement counterfactual experiment. Higher antitrust decision anticipation requires higher obstruction probability ι to be consistent with the observed obstruction rate in the data. This revises the estimated strength of existing antitrust enforcement upwards. Consequently, its dynamic growth and welfare impact is calculated to be larger than in the baseline estimation, as shown in Table A1. We conclude that the positive growth and welfare effects of existing antitrust policy may be larger than what we have calculated using the baseline model, and therefore these quantities constitute a lower bound.

5.2 Elastic Labor Supply

In our baseline model, we assume an inelastic labor supply. As a result, the estimated welfare implications of antitrust policies ignore the potential effect of those policies on labor supply. In Section A.3, we extend our baseline model by allowing for elastic labor supply and disutility from labor, and investigate the resulting welfare implications compared to our baseline model. We find that the impact of antitrust policy on the labor supply, relative wage, and consumption-equivalent welfare change remains limited, delivering almost identical quantitative results, as seen in Table A2. This is consistent with the observation in our baseline model that changes in the relative wage caused by our experiments do not affect welfare significantly (see Table 5), and that the dynamic welfare effects are an order of magnitude larger than the static ones. Therefore, we conclude that the quantitative results of our model do not substantially change when we allow for elastic labor supply.

6 Conclusion

The recent literature on antitrust highlights some potential shortcomings of current antitrust policies, with a particular emphasis on the lack of dynamic considerations when investigating mergers and acquisitions. In this context, our paper proposes the first general equilibrium model with endogenous growth that allows the study of the growth and welfare effects of antitrust policies in a dynamic framework. We build a Schumpeterian model of growth through innovation with an endogenous number of small and large firms within each industry, endogenous entry and exit of both small and large firms, heterogeneous markups, and non-degenerate sales distributions within industry. This allows us to obtain realistic firm and industry dynamics and measures of market concentration as well as to replicate the empirical relationship between innovation and concentration within and across industries. We explicitly model mergers and antitrust policy consistent with the guidelines set by US antitrust authorities. These features allow for a careful study of existing HHI-based antitrust policies and of their effects on growth and welfare.

Using our estimated model, we perform several counterfactual experiments. We show that welfare would be 0.49% lower in consumption-equivalent terms in the absence of antitrust policies. Strengthening antitrust enforcement can substantially increase the welfare gains. We find that the dynamic effects of antitrust policies on welfare, linked to innovation, are an order of magnitude larger than their static effects, supporting the idea that antitrust policies should take into account innovation and its associated dynamic efficiency gains, and that exclusive focus on HHI might be misleading. We show that strengthening the enforcement of antitrust policies can boost innovation, promote economic growth, and lead to sizeable improvements in social welfare. The estimated model also reveals that the current HHI-based antitrust rules leave an overwhelming majority of anticompetitive acquisitions undetected, highlighting the need for alternative guidelines which could capture anticompetitive acquisitions that involve currently small, but potentially very innovative targets.

Given its richness, our model offers a new framework to analyze in a dynamic setting other types of competition policies targeting, for instance, cartel formation or collusion, and abuse of dominant position. Another important direction for future research is to study optimal rules for antitrust interventions taking into account their implications for both static and dynamic efficiencies, while putting more emphasis on industry-specific information. It would be interesting to utilize and extend our current framework to explore what government policies, besides existing HHI-based antitrust rules, could better safeguard the interests of consumers, stimulate innovation, promote economic growth, and maximize social welfare. A mix of ex-ante antitrust probes and fines, together with ex-post interventions, may serve these goals. We expect future research along these lines to be both promising and fruitful.

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Online Material for "The Dynamic Effects of Antitrust Policy on Growth and Welfare" (Not for Publication)

A Appendix

A.1 Proposition 1

Let $\hat{\Theta}$ denote the set of all industry-states Θ. Let $h : \hat{\Theta} \to \mathbb{R}$ be a function. Let $p(\Theta, \Theta')$ denote the instantaneous flow from industry-state Θ to Θ'. Then, in a stationary equilibrium:

$$\begin{aligned}
\mathbb{E}\left[\sum_{\Theta'} p(\Theta,\Theta')(h(\Theta') - h(\Theta))\right] &= \sum_{\Theta}\sum_{\Theta'} p(\Theta,\Theta')(h(\Theta') - h(\Theta))\mu(\Theta) \\
&= \sum_{\Theta}\sum_{\Theta'} p(\Theta,\Theta')h(\Theta')\mu(\Theta) - \sum_{\Theta}\sum_{\Theta'} p(\Theta,\Theta')h(\Theta)\mu(\Theta) \\
&= \sum_{\Theta'} h(\Theta') \sum_{\Theta} p(\Theta,\Theta')\mu(\Theta) - \sum_{\Theta} h(\Theta) \sum_{\Theta'} p(\Theta,\Theta')\mu(\Theta) \\
&= \sum_{\Theta'} h(\Theta')\mu(\Theta') - \sum_{\Theta} h(\Theta)\mu(\Theta) \\
&= \mathbb{E}\left[h(\Theta')\right] - \mathbb{E}\left[h(\Theta)\right] \\
&= 0
\end{aligned}$$

A.2 Antitrust Decision Anticipation

In our baseline model, firms that would like to merge (due to positive expected total surplus from merging) are aware of the policies employed by the antitrust authorities, but they do not have perfect information regarding the outcome. In the case of mergers that are subject to investigation given the HHI thresholds, the antitrust authorities block a merger with probability $\iota \in [0,1]$. The firms are aware of this probability, but they cannot predict the outcome with certainty before they initiate a merger transaction.

It is possible that firms in the real world have more information regarding the potential outcome of a merger transaction proposal. If firms can anticipate that their merger transaction will be blocked by the authorities with reasonable accuracy, they might be dissuaded from applying for a merger in the first place. In such a setting, the empirically observed probability of merger obstruction would be lower than the (unobserved) true merger obstruction rate: some additional potential mergers are obstructed, but we never observe them in the data since the firms do not apply for a merger in the first place, given that they can anticipate the negative outcome in advance. If this is the case, there can be many more potential mergers that are obstructed under the current antitrust regime that we never observe, and the obstructions we observe might just be “the tip of the iceberg”, so to speak. This could mean that shutting down antitrust enforcement can increase the number of anticompetitive mergers more than what our baseline model predicts in Section 4.5, and therefore lead to more substantial growth and welfare losses.

In this section, we develop an extended model in which we allow firms to anticipate the decision of the antitrust authorities before they apply for a merger with some probability $\Upsilon \in [0, 1]$. Given this information, firms can choose not to apply for a merger in the first place, knowing that the deal will be rejected. This generates a wedge between the observed merger obstruction rate, and the unobserved true merger obstruction rate. We then re-estimate the model under different values for the anticipation probability Υ, repeat the no antitrust enforcement counterfactual experiment using the extended model in each of the estimated economies, and show how much the welfare results would differ compared to the baseline model.

A.2.1 Extended Model with Antitrust Decision Anticipation

Conditional on a meeting between two superstar firms, the timeline of events is modified as follows:

1. The two firms observe the merger cost φ drawn from $G(\varphi)$, and calculate the expected total surplus they would generate if they were to merge.

2. As in the baseline model, the firms can perfectly predict whether their merger will be subject to investigation or not, based on the explicitly announced thresholds regarding HHI_M and ΔHHI_M. If the merger is not investigated, it will be allowed with probability one, and this is public information.

3. In the case of merger transactions subject to investigation, the authorities block the merger with probability $\iota \in [0, 1]$, and let it occur with probability $1 - \iota$. Unlike in the baseline model, the firms now have a chance to anticipate the decision of the antitrust authorities conditional on an investigation. The two firms can perfectly anticipate the result of this Bernoulli random variable with probability $\Upsilon \in [0, 1]$. With the complementary probability, they remain in the dark and have to rely on their rational expectations regarding the outcome.[20]

4. After the firms acquire the listed information, they choose whether to apply for a merger or not.

5. Conditional on a merger application, the antitrust decision is observed, and the merger outcome is realized.

Under this new structure, the merger application decisions remain the same as in the baseline model except for one particular scenario: consider a meeting between two firms who

[20]Therefore, setting $\Upsilon = 0$ collapses the model back to our baseline framework.

would like to merge (positive expected total surplus), know that their merger is subject to investigation ($\frac{HHI_M}{\kappa} \geq 0.15$ and $\frac{\Delta HHI_M}{\kappa} \geq 0.01$), can anticipate the antitrust decision (with probability: Υ), and know that they will be obstructed if they apply (with probability: ι). Under such a scenario, the two firms would strictly prefer not to apply given any positive application cost.[21] Such cases constitute merger obstructions that are not observed — the two firms would have liked to merge, but they are dissuaded from applying, anticipating that their merger transaction will be obstructed by the antitrust authorities. Therefore, they never apply in the first place, and we do not observe this obstruction as the econometrician. The only obstruction cases that are observed in equilibrium are the instances when the firms cannot anticipate the outcome, and apply without full information (with probability: $1 - \Upsilon$). This creates a wedge between the observed obstruction rate and the unobserved true obstruction rate, the size of which is increasing in the anticipation probability Υ.

A.2.2 Estimation and Quantitative Results

The baseline model presented in the main text corresponds to the extended model with $\Upsilon = 0$. Increasing Υ while holding all other parameters constant decreases the observed obstruction rate, but keeps the unobserved true obstruction rate constant.

Recall that two moments that were used to estimate the baseline model were the average (observed) obstruction rate and the average (annual) merger probability. The average observed obstruction rate disciplined the obstruction probability conditional on investigation ι, and the average merger probability was used to identify the merger arrival rate σ. Since values of antitrust decision anticipation probability Υ higher than zero decrease the observed obstruction rate, the value of ι must be increased compared to the baseline estimation so that the model can still hit the empirically observed obstruction rate. At the same time, increasing the value of ι itself results in more mergers being obstructed, reducing the average merger rate. For the model to hit the empirically observed average merger rate, the value of σ must be increased.

We re-estimate the model for three different values of the anticipation probability $\Upsilon \in \{0.25, 0.50, 0.75\}$, and call these the low, medium, and high anticipation scenarios, respectively. This involves changing the values of the parameters ι and σ for each value of Υ such that the model is still consistent with the empirically observed average obstruction rate and average merger rate.[22]

Table A1 presents the results of this re-estimation exercise, and its quantitative impact on the model predictions. The first column corresponds to the baseline model with no

[21] An arbitrarily small yet positive application cost suffices for this result.

[22] The values of other parameters do not need to be changed, since hitting the two moments while keeping other parameters the same results in the remaining moments being hit just as well as in the baseline estimation.

Table A1: Quantitative Results for the Extended Model with Antitrust Decision Anticipation

	No Anticipation	Low Anticipation	Medium Anticipation	High Anticipation
anticipation probability (Υ)	0.0000	0.2500	0.5000	0.7500
obstruction probability (ι)	0.0594	0.0790	0.1158	0.2192
merger arrival rate (σ)	0.1728	0.1733	0.1745	0.1783
average merger probability	3.83%	3.83%	3.83%	3.83%
observed avg. obstruction rate	0.88%	0.88%	0.88%	0.88%
true obstruction rate (unobserved)	0.88%	1.17%	1.74%	3.42%
unobserved to observed obst. ratio	0.000	0.329	0.983	2.897
No Antitrust - CEWC	-0.491%	-0.657%	-0.977%	-1.929%
No Antitrust - growth pct. change	-0.877%	-1.173%	-1.743%	-3.441%

anticipation, whereas the remaining columns correspond to the low, medium, and high anticipation scenarios, respectively. The first three rows report the imposed value of Υ, and the estimated values of ι and σ. The fourth and fifth rows report the data moments: average merger probability and observed average obstruction rate. As can be seen, the two moments are hit just as accurately after re-estimation in all scenarios. To achieve this, the estimated value of ι has to increase roughly by $\frac{\Upsilon}{1-\Upsilon}$. However, since the fraction of mergers that are obstructed are quite low even under the high anticipation scenario, the estimated value of the merger arrival rate σ has to increase by a much smaller proportion in comparison.

Given the underlying anticipation probability Υ, our model allows the calculation of the unobserved true obstruction rate, which also includes potentially profitable mergers that are deterred due to the anticipation of an obstruction decision, which is displayed in the sixth row of Table A1. The seventh row reports the ratio of such unobserved obstructions to the empirically observed obstruction decisions. The true obstruction rate is one third higher with $\Upsilon = 0.25$, doubled with $\Upsilon = 0.50$, and quadrupled with $\Upsilon = 0.75$. As can be gleaned from the seventh row, the "part of the iceberg underwater" is increasing in the anticipation probability Υ. In the low anticipation case, the unobserved obstructions are one third of the observed ones. In the medium anticipation case, the numbers are roughly equal. In the high anticipation case, the observed obstruction cases are just the tip of the iceberg, and constitute only a quarter of all obstructions.

How do changes in antitrust decision anticipation affect the estimated quantitative importance of existing antitrust enforcement? As discussed, higher values of Υ require higher values of ι to be consistent with the data moments. This revises the estimated strength of existing antitrust enforcement upwards. Consequently, the dynamic growth and welfare impact of existing antitrust policy is calculated to be larger than in the baseline estimation. The last two rows of Table A1 report the consumption-equivalent welfare change and the percentage change in aggregate productivity growth when we repeat the antitrust shutdown experiment described in Section 4.5 with the three re-estimated economies using the extended model. The dynamic impact on both welfare and productivity growth is amplified in proportion to the increase in the true obstruction rate: the impact is one third higher with $\Upsilon = 0.25$, doubled with $\Upsilon = 0.50$, and quadrupled with $\Upsilon = 0.75$. In absolute terms, under the high anticipation scenario, the consumption-equivalent welfare loss from shutting down antitrust is found to be 1.929%, a much more significant amount compared to the 0.491% calculated with the baseline model.

How to interpret these findings? While we are of the opinion that anticipation of antitrust decisions ahead of time is a likely scenario in reality, estimating its extent requires information on the number of unobserved merger obstruction cases – profitable merger opportunities that are never converted into applications. This information is, by its very nature, difficult to elicit. Given the quantitative results from our extended model, we conclude that the positive growth and welfare effects of existing antitrust policy may be larger than what we have calculated using the baseline model, and therefore these quantities constitute a lower bound.

A.3 Extended Model with Elastic Labor Supply

In our baseline model, we assume an inelastic labor supply. As a result, the welfare implications of antitrust policies ignore the potential effect of those policies on labor supply. In this section, we propose an extension of our model with elastic labor supply and investigate the resulting welfare implications compared to our baseline model.

We extend our baseline model by allowing for elastic labor supply and disutility from labor. The representative household chooses consumption (C_t) and labor supply (L_t) to maximize:

$$U = \int_{t=0}^{\infty} e^{-\rho t} \left(\ln C_t - \Lambda \frac{L_t^{1+\beta}}{1+\beta} \right) dt \text{ subject to} \tag{42}$$

$$\dot{A}_t = r_t A_t + w_t L_t - C_t \tag{43}$$

where $\Lambda \geq 0$ is a scale parameter, and β is the inverse of the Frisch elasticity of labor supply. We can write the current-value Hamiltonian with costate variable Γ_t as:

$$H(t, A_t, C_t, L_t, \Upsilon_t) = \ln C_t - \Lambda \frac{L_t^{1+\beta}}{1+\beta} + \Gamma_t (r_t A_t + w_t L_t - C_t) \tag{44}$$

which delivers the usual Euler equation $\frac{\dot{C}_t}{C_t} = r_t - \rho$ and the following intratemporal optimality condition:

$$\Lambda L_t^{\beta} = \frac{w_t}{C_t}$$

$$L_t = \left(\omega_t \left(\frac{C_t}{Y_t}\right)^{-1} \frac{1}{\Lambda}\right)^{\frac{1}{\beta}} \tag{45}$$

Labor market clearing requires that labor demand equals labor supply in equilibrium. In a balanced growth path, we can further rewrite welfare as:

$$W = \int_{t=0}^{\infty} e^{-\rho t} \left(\ln(C_0 e^{gt}) - \Lambda \frac{L^{1+\beta}}{1+\beta}\right) dt \tag{46}$$

$$= \frac{\ln(C_0)}{\rho} + \frac{g}{\rho^2} - \frac{\Lambda L^{1+\beta}}{\rho(1+\beta)} \tag{47}$$

For two economies A and B, we can also define a consumption-equivalent welfare measure (ϖ) which corresponds to the percentage increase in lifetime consumption that an agent in economy A would need to be indifferent between being in economy A and B:

$$W_B = \frac{\ln(C_0^A(1+\varpi))}{\rho} + \frac{g^A}{\rho^2} - \frac{\Lambda (L^A)^{1+\beta}}{\rho(1+\beta)} \tag{48}$$

Solving for ϖ, we get:

$$\varpi = \exp\left(\left(W_B - \frac{g^A}{\rho^2} + \frac{\Lambda (L^A)^{1+\beta}}{\rho(1+\beta)}\right)\rho - \ln(C_0^A)\right) - 1 \tag{49}$$

Turning to the quantitative experiments, we first calibrate the two additional parameters and choose a Frisch elasticity of one equivalent to $\beta = 1$. Without loss of generality, we normalize total labor L_t in the estimated equilibrium to one by setting Λ equal to:

$$\Lambda = \omega_t \left(\frac{C_t}{Y_t}\right)^{-1} \tag{50}$$

The estimated value of Λ is simply the relative wage rate divided by the consumption to output ratio in the estimated equilibrium of the model with inelastic labor supply, since in the baseline model the inelastic labor supply is likewise normalized to one. The values of all other parameters and the model fit remain the same as in the baseline model.

We repeat our three main experiments, i.e. shutting down antitrust policy and stronger antitrust policies through lowering the HHI thresholds and increasing the obstruction rate conditional on investigation. We report the welfare results in Table A2.

Table A2: Baseline vs. Extended Model with Elastic Labor Supply

Panel A: Baseline Model

Experiment	CEWC	Relative Wage	Labor Supply
No Antitrust	-0.4908%	0.80881	1.00000
Lower HHI Thresholds	1.9719%	0.80865	1.00000
Higher Obstruction Rate	2.2874%	0.80838	1.00000

Panel B: Labor Extension

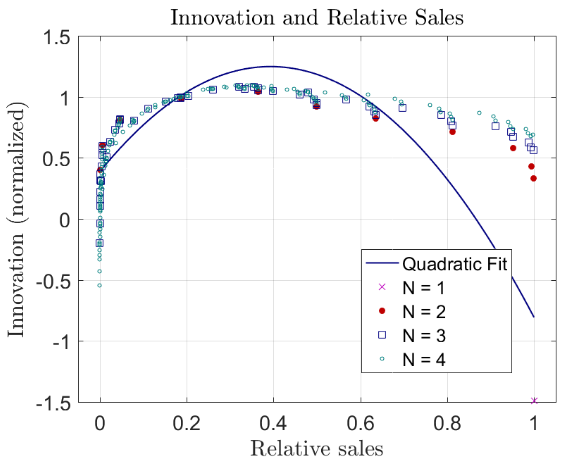
Experiment	CEWC	Relative Wage	Labor Supply
No Antitrust	-0.4906%	0.80880	1.00001
Lower HHI Thresholds	1.9717%	0.80866	0.99999
Higher Obstruction Rate	2.2863%	0.80843	0.99994

Panel C: % change

Experiment	CEWC	Relative Wage	Labor Supply
No Antitrust	-0.0435%	-0.0012%	0.0012%
Lower HHI Thresholds	-0.0072%	0.0008%	-0.0008%
Higher Obstruction Rate	-0.0448%	0.0057%	-0.0057%

Shutting down antitrust policy in our model with elastic labor supply causes a very small increase in labor supply (see Panel B of Table A2). This results in a very slightly larger decrease in relative wage compared to our baseline model with inelastic labor supply (Panel A of Table A2). Stronger antitrust policy enforcement either through decreased HHI thresholds and increased obstruction rates results in very small decrease in labor supply and relative increase in relative wage compared to our baseline model. Our baseline model already showed that changes in the relative wage through our experiments did not affect welfare significantly (see Table 5), and that the dynamic welfare effects are an order of magnitude larger than the static ones. As a result, the very tiny changes in relative wages and labor supply in our extension of the model with elastic labor supply barely affects our welfare results quantitatively. Panel C displays the percentage change in welfare, relative wage, and labor supply in the extended model with elastic labor supply compared to the baseline model. As can be seen, the changes are all below one thousandth of their value. Overall, we conclude that the quantitative results of our model do not substantially change when we allow for elastic labor supply.

B Additional Figures



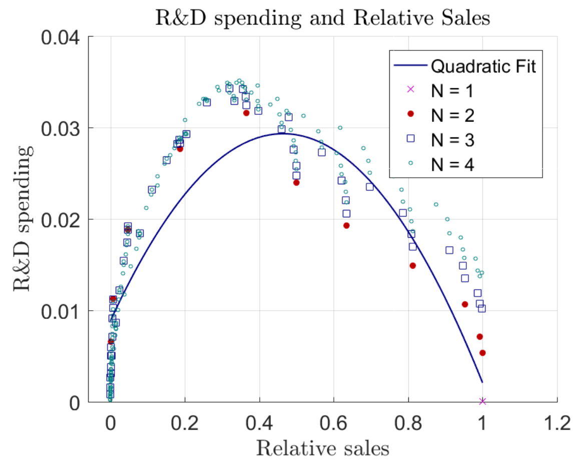


Figure B1: Firm Innovation, R&D Expenses, and Relative Sales

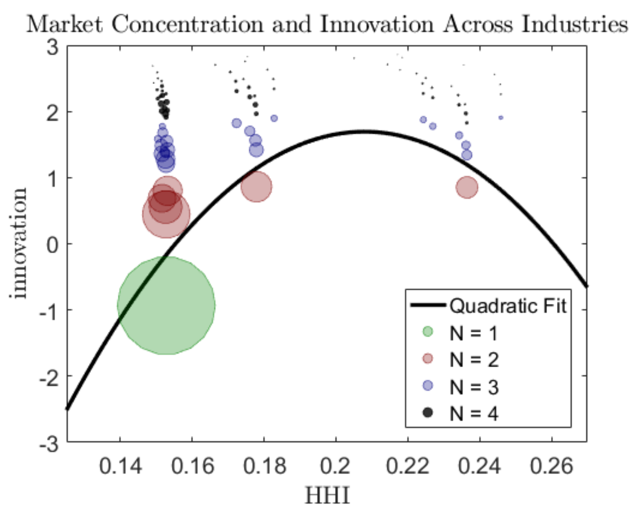


Figure B2: Total Industry Innovation and HHI