Competition Policy in Light of Innovation

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Abstract

Horizontal mergers impact welfare along several dimensions: they change markups; cost synergies increase productivity; by increasing profits, mergers encourage entry; by altering the competitive landscape, mergers affect firms' investment in productivity growth; and mergers reduce wasteful duplication of research. This paper presents a new dynamic general equilibrium model that incorporates these dimensions and quantitatively evaluates merger policies. We find that the social value of an antitrust authority is very large, and price-based policies perform best. Competition policy improves welfare mainly by encouraging innovation-driven growth, rather than lowering markups. Still, higher markups are symptomatic of decreased competition, hence slower growth.

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"[...] *Congress passed antitrust laws to promote a host of political economic ends—including our interests as workers, producers, entrepreneurs, and citizens*." Lina Khan (2016, p. 737)

1 Introduction

Mergers, acquisitions, and innovation are among the most impactful economic activities, with competition policy in the fold of these fundamental forces of economic progress. Our goal in this paper is to develop and calibrate a rich but tractable model that helps inform competition policy in light of its effects on innovation and growth. Specifically, we quantitatively evaluate several merger policies by developing and calibrating a new dynamic general equilibrium model that features oligopolized industries with endogenous entry, entry barriers, exit, mergers, and growth through innovation by forward-looking households and firms.

Horizontal mergers impact welfare in several ways. Statically, mergers increase deadweight losses from market power, but decrease costs when there are merger synergies. Dynamically, increased market power as a result of mergers encourages entry. Mergers affect investment in productivity growth among incumbents, too, as do knowledge spillovers and selection effects on firm survival. In addition, mergers reduce wasteful spending due to the duplication of research. Our calibrated model determines the relative importance of each of these effects. Broadly, our main result is that dynamic considerations—especially economic growth through innovation and spillovers—are an order of magnitude more important than static ones, such as markups, for optimal merger policy. However, we also find that high markups are symptomatic of low competition, and low competition leads to productivity stagnation, so despite a tenuous direct link between (static) markups and (dynamic) welfare, markups and growth tend to be negatively related. This vindicates the use of merger policy guided by market power.

The economic importance of merger policy is difficult to overstate. In practice, though, policy debates tend to center around the static logic of deadweight losses and market concentration. Apart from a few recent papers discussed below,[1] dynamic evaluation of merger policy remains understudied. Our goal is to fill this void; we hope that our model addresses frustrations voiced by policymakers over viewing competition policy from a static lens. Perhaps most visibly, Khan (2016, 2018) argued that antitrust law would benefit from more "structural reasoning," since otherwise it "[...] *would replicate a key mistake of the Chicago School: overriding a structural inquiry about process and power with one that focuses on a narrow set of outcomes. Refocusing antitrust on structures and a broader set of measures to assess market power can return the law to focusing on the competitive process.*" (Khan, 2018, p. 132.) This so-called "Neo-Brandeisian" approach seems to reconcile two basic tenets of competition policy. On the one hand, as Brandeis argued,[2] "[...] *unless there be regulation of competition, its excesses will lead to the destruction of competition, and monopoly will take its place*." On

[1] See, e.g., Igami and Uetake (2020), Mermelstein et al. (2020), David (2021), Cavenaile et al. (2021) and Fons-Rosen et al. (2023). As we show below, our paper has a richer framework with new quantitative results.

[2] Louis Brandeis, 1912, "The Regulation of Competition Against the Regulation of Monopoly."

the other hand, according to Schumpeter,[3] "[...] *in capitalist reality as distinguished from its textbook picture, it is not that kind of competition which counts but the competition from the new commodity, the new technology, the new source of supply, the new type of organization* [...] *which commands a decisive cost or quality advantage and which strikes not at the margins of the profits and the outputs of the existing firms but at their foundations and their very lives*." Such concerns over "creative destruction" have garnered much urgency—the European Commission recently published the highly influential "Draghi report," a blueprint for European competitiveness emphasizing the need to incorporate innovation and growth in competition policy, which may be summarized as follows: "*Competition authorities need to be more forward-looking and agile*." (Draghi, 2024, Part B, p. 299.)

1.1 Overview of Main Results

Our policy evaluation shows that economic growth through innovation supersedes the goal of lowering markups, although protecting consumers from harmful market structures remains valuable in the long run. To prevent mergers that reduce economic dynamism, our analysis suggests that the best merger policies are stricter than the static benchmark of not reducing consumer surplus, and stricter than the status quo: both welfare and economic growth could increase with a stricter merger policy than the current one.

Table 1 below presents some of the main results from our model calibrated to the US economy (Section 4 has the details). For context, we first report that allowing all merger applications to proceed would severely hinder prosperity, in terms of both welfare and economic growth (see Table 1, 'Monopoly'), relative to our calibrated status quo merger policy. (Our assumed status quo policy is discussed in Section 4. Welfare in Table 1 is normalized relative to it.) Moreover, forbidding all mergers is better than green-lighting them all, and also improves on the status quo. The 2023 merger guidelines (DOJ and FTC, 2023), discussed in Section 4, generate more welfare than forbidding all mergers, despite inducing higher markups.

Table 1 reports results from several other policies: (i) N_{min}, where a merger request is granted only if the resulting number of firms in an industry is above a threshold (our status quo is $N_{min} = 3$, and our optimal threshold is 5),[4] (ii) ΔHHI, where the Herfindahl index cannot increase by more than a threshold post-merger (the optimum is about 10), (iii) Δp, where market prices cannot increase by more than a threshold immediately after a merger (the optimum is -0.5%), and (iv) $\alpha\beta$, explained below, where the price threshold internalizes an endogenous entry barrier. The 'Static' policy of Table 1 corresponds to $\Delta p = 0$, i.e., a merger may not increase industry equilibrium prices, or, equivalently, reduce consumer surplus.

[3] Joseph Schumpeter, 1942, "Capitalism, Socialism and Democracy," Chapter VII.

[4] Though not in Table 1, we also studied HHI policies where mergers must leave their industry's post-merger Herfindahl index below some threshold. (Our optimum threshold was about 2400; see Section 5 for details.)

	Optimal Policy	*Welfare*	*Avg. Markup*	*Merger rate*	*GDP Growth*
Monopoly	–	0.466	45.7%	11.60%	1.36%
Status Quo	–	1.000	27.5%	4.45%	1.61%
No Mergers	–	1.049	25.9%	0.00%	1.64%
2023 Guidelines	–	1.061	26.3%	3.07%	1.65%
N_{min}	5	1.064	25.8%	0.48%	1.65%
ΔHHI	10	1.065	25.8%	1.02%	1.65%
"Static"	–	1.098	26.5%	2.85%	1.68%
Δp	-0.50%	1.107	26.4%	2.24%	1.69%
$\alpha\beta$	$(0, -6\%)$	1.113	26.4%	2.83%	1.69%

Table 1: Comparison of Policies by Welfare, Markups, and GDP Growth

According to Table 1, the US's merger policy may be too lax, since the optimal N_{min} threshold of 5 is greater than the calibrated status quo of $N_{\text{min}} = 3$. Moreover, welfare under this status quo is much greater than under the monopoly policy of $N_{\text{min}} = 1$, where the merger rate jumps from 4.45% to 11.6%, and growth decreases by 25 basis points, suggesting that antitrust matters a lot for long-run growth.[5] The other policies reported above seem to overcome this monopoly problem and make modest gains beyond the status quo, too, with growth varying by at most 8 basis points for optimal N_{min}, HHI-based and price policies alike. This calls into question the value of fine-tuning merger policies. Still, Table 1 confirms that reducing merger rates indiscriminately does not necessarily increase welfare.

The last three rows of Table 1 describe price-based policies, which clearly outperform the rest. Roughly, prices summarize productivity and demand elasticity well, so price decreases help to flag valuable mergers in terms of static welfare. The 'Static' price policy above outperforms all of the aforementioned non-price policies, including the 2023 merger guidelines. Thus, the static rationale demanding that mergers not decrease consumer surplus is a good policy heuristic. Confirming this intuition, Table 1 shows that an optimal price policy is only slightly more strict: mergers must decrease prices by at least -0.50% to be allowed to go through. The last row of Table 1 reports results from an optimal $\alpha\beta$ policy, explained in detail later, which outperforms all other policies we considered by discriminating along endogenous entry barriers. Generally speaking, from our comparative statics calculations (Appendix B), we found our results to be robust to some assumptions but sensitive to others.[6]

[5] The extreme case of allowing all mergers to go through is far from our calibration, so these specific quantitative results should not be taken literally. Nevertheless, the huge difference between monopoly and the status quo suggests that the effect of merger policy is substantial. See Section 5 for further discussion.

[6] For example, if entry of new firms is exogenous, optimal policy changes very little, but if expected merger synergies double from our calibrated value, merger policy changes substantially and becomes more permissive of mergers. Perhaps surprisingly, changing the Frisch elasticity of labor supply—which controls most of the deadweight losses from market power—did not change optimal policy much.

To glean the mechanics of our results, Figure 1 below presents some outcomes of the calibrated balanced-growth path of our model across a range of thresholds of a Δp policy on each x axis (increasing the threshold relaxes the policy). Welfare is maximized at $\Delta p = -0.50\%$, which also maximizes growth. (The 'static' policy of $\Delta p = 0$ performs only slightly worse.) Labor supply is decreasing in the threshold, as are exit, the average number of firms per industry, and average investment. However, markups, entry and, of course, mergers, increase. Increasing the price threshold (i.e., relaxing merger policy) so that the merger rate increases by 1 percentage point from our calibrated 4.45% decreases economic growth by around 2 basis points, and innovation by around 1. Thus, quantitatively, merger policy matters at the margin.

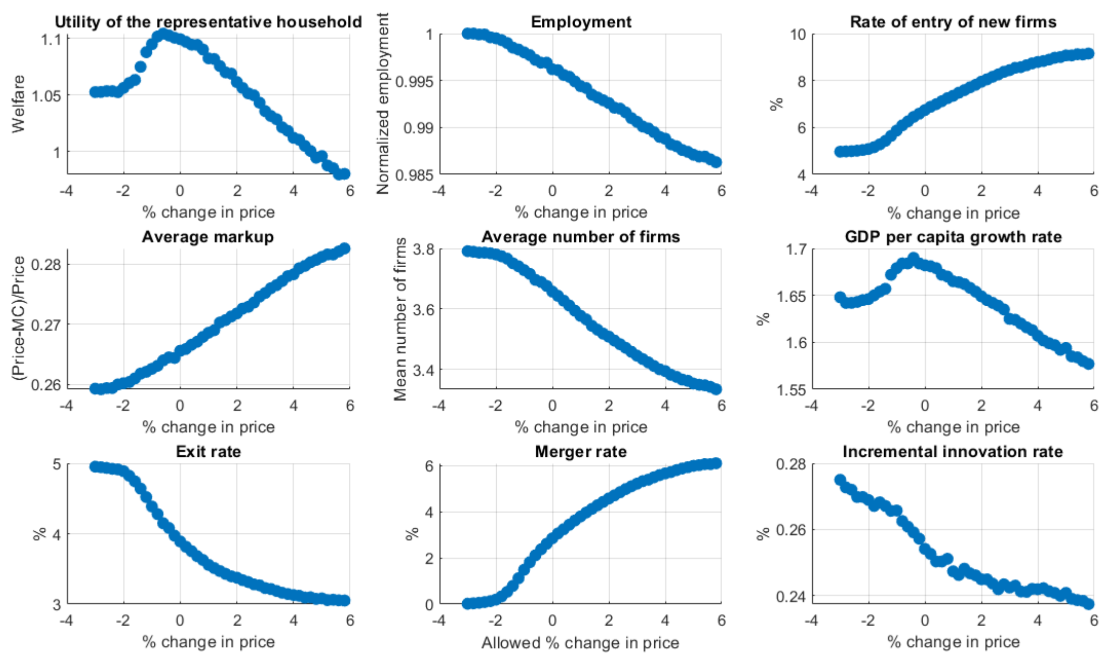

Figure 1: Economic outcomes (y axes) under different Δp pricing thresholds (x axes).

Figure 1 exposes a basic trade-off. On one hand, allowing more mergers (by increasing Δp) increases entry, and cost synergies from mergers push up growth. On the other hand, the average number of firms decreases despite more entry and less exit, which pushes down growth because aggregate investment in innovation decreases. Of course, markups rise with increased market concentration, but the decrease in growth from reduced innovation matters an order of magnitude more for welfare than increased static deadweight losses, since the latter are just level effects. Section 5.2 shows that dynamic effects of merger policy account for 87% and static effects for 13%.[7] This result is relatively robust to Rawlsian reasoning (Section 5.4).[8]

[7]Most of the static effect is driven by aggregate deadweight losses from market power reflected in the labor market, with 2 percentage points driven by inefficiency from differences in markups across industries.

[8]Although optimal policy for working households (earning labor income only) tends towards allowing even fewer mergers (now $\Delta p = -0.75\%$ is optimal) because more lax merger policy decreases income's labor share, overall income grows at the same rate as labor income.

1.2 Overview of the Model

To explain the results above, let us summarize our model. Consider a long-lived representative household that, over time, consumes a continuum of good varieties produced by firms, supplies labor to them imperfectly elastically,[9] and exerts entrepreneurial effort to create new firms. Each good variety is produced by forward-looking firms in oligopolistic competition, who compete in quantities and invest in innovation to improve their productivity.[10] Over time, new firms occasionally enter the market for a particular variety, poorly performing firms exit endogenously, and synergistic merger opportunities present themselves to incumbents. For a merger opportunity to become an actual merger, it must be approved by the merger authority and rendered profitable in present value terms by the merging firms. Merger policy enters this calculation subtly, since the prospect of future approved mergers by both a merging firm and its competitors impacts the profitability of current merger opportunities.

Economic growth is driven by firms investing in innovation to become more productive, cost synergies from mergers, entry of new firms into less-productive industries, and knowledge spillovers, where laggards tend to catch-up to productivity leaders, all else equal.[11] New firms' initial productivity is proportional to the economy-wide mean (as in Lucas, 1988), its industry's mean, and a shock. To match the data, our calibration implies that (i) entrants tend to be less productive than incumbents, and (ii) firms entering more productive industries find it harder to survive, whereas those entering less productive ones find it easier to thrive. This creates endogenous entry barriers in line with an industry's productivity.

Thus, merger policy that fosters growth should confront different industries differently. On one hand, lax policy allows firms in industries with bigger entry barriers to merge towards monopoly, reducing their incentive to grow through innovation.[12] As such, mergers can have long-lasting pernicious effects in these industries. On the other hand, with low entry barriers, firms should grow by merging, since high entry rates reduce both innovation incentives and mergers' pernicious effects. A natural policy response is to permit more mergers in low-barrier industries than high-barrier ones. Our $\alpha\beta$ policies, whose price-change thresholds depend on industry productivity, do just that by gradually allowing fewer mergers in an industry as it becomes more productive, in a way that respects innovation incentives as industries grow.[13]

[9] This generates static deadweight losses from market power via reduced labor supply, output and wages.

[10] In line with the literature, discussed below, firms make these decisions in Markov perfect equilibrium.

[11] Some of these growth factors appear in previous work, such as Cavenaile et al. (2021), David (2021) and Fons-Rosen et al. (2023), but crucial differences remain in both our model and its calibration; see Section 1.3.

[12] This logic resonates with the 'inverted-U' between competition and innovation due to Aghion et al. (1997), Aghion et al. (2001) and Aghion et al. (2005); see also Kamien and Schwartz (1976). More recently, Akcigit and Kerr (2018), Garcia-Macia et al. (2019) and Atkeson and Burstein (2019) extend the Klette and Kortum (2004) model to measure creative destruction in various contexts. See also Jovanovic and Rob (1989).

[13] This may justify the FTC's tactic of only inspecting a small subset of the merger applications it receives.

Methodologically, we develop new quantitative methods to accommodate differences in firm behavior across heterogeneous industries. To do so, we extend previous quality-ladder models in substantial ways. These models assume that households' demand elasticity of substitution over good varieties always equals one, and there is Bertrand competition within industries; therefore, revenue shares across industries are constant, and the state of an oligopolized industry can be summarized by its firms' productivity gap from the industry leader. Thus, by construction, innovation incentives only depend on this gap in quality-ladder models.

Being incompatible with monopoly, we relax the assumption of unit-elastic demand.[14] Thus, revenue shares are no longer constant across industries, and firms' innovation decisions depend on more than just productivity gaps with direct competitors. Varying revenue shares give firms inherent incentives to improve their productivity, so firms in industries with different mean productivity *levels* behave differently.[15] This increases significantly the dimensionality of the state of the economy, since firms' decisions now depend not only on their own productivity and their direct competitors', but also on their industry's overall productivity relative to the entire economy. Our computational innovation includes developing a numerical method that tames this dimensionality increase to calibrate our richer model with endogenous entry, exit, and merger decisions. Specifically, we approximate our high-dimensional model by iteratively simulating its economy and estimating firms' value functions across industry-productivity quantiles to capture endogenous firm and industry investment heterogeneity, until we near a fixed point. Each value function in turn estimates the state of an industry—its productivity profile—at its productivity quantile to compute equilibrium innovation decisions.

Table 2 below shows how this interacting industry heterogeneity can influence merger policy. It displays the distribution of industries by average productivity quartile and number of firms in the industry. The distribution on the left corresponds to the monopoly policy of Table 1 and the one on the right corresponds to the optimal $\alpha\beta$ policy. As Table 2 shows, under the monopoly policy there are many monopolistic industries, most of them less productive. An 'inverted-U' between number of firms and frequency of top-quartile industries is apparent, too. The right distribution shows how merger policy can practically stamp out monopoly, and thus skew the industry distribution towards more firms on average, which by virtue of competition invest more in innovation and thus tend to belong to higher quartiles. Table 2 also shows that the average number of firms increases from 2 to 3 with higher industry productivity quartiles under monopoly and decreases from about 4.5 to about 3.2 under an optimal $\alpha\beta$ policy. Thus, the optimal $\alpha\beta$ policy harnesses market concentration towards higher productivity.

[14] Otherwise, a monopolist could produce arbitrarily little output and still secure a fixed revenue, which clearly kills innovation incentives. As such, quality-ladder models like Acemoglu and Akcigit (2012), Cavenaile et al. (2021) and Fons-Rosen et al. (2023) assume at least two firms in an industry. See Section 1.3.

[15] This is on top of the heterogeneity of incentives from differences in entry barriers discussed before.

	Monopoly Policy				*Optimal $\alpha\beta$ Policy*			
No. Firms	*Q1*	*Q2*	*Q3*	*Q4*	*Q1*	*Q2*	*Q3*	*Q4*
1	20.12	6.42	3.92	5.28	0.00	0.00	0.00	0.02
2	3.65	1.53	0.75	0.79	0.35	0.37	0.50	4.76
3	4.05	3.13	3.45	15.95	5.02	5.18	5.97	12.94
4	3.97	4.32	3.78	8.00	10.11	9.55	8.66	6.79
5	2.23	2.63	1.77	1.51	8.01	7.01	4.22	1.29
6	0.82	0.87	0.49	0.13	3.40	2.46	0.81	0.12
7	0.17	0.16	0.08	0.01	0.88	0.50	0.10	0.00
8	0.02	0.01	0.00	0.00	0.14	0.06	0.00	0.00
Avg.	2.08	2.92	3.04	3.00	4.44	4.31	3.96	3.19

Table 2: Percentage of industries by mean industry productivity quartile and number of firms, for monopoly (left) and optimal $\alpha\beta$ (right) merger policies. See Section 5 for further details.

Figure 2 below summarizes the importance of generalizing quality-ladder models by showing its substantial impact on our calibrated economy. For comparison, we shut down industry heterogeneity by imposing unit-elastic demand and homogeneous entry barriers.[16] To test the sensitivity of the economy to merger policy, Figure 2 shows welfare in relation to increasingly lenient Δp thresholds. Thus, the blue curve corresponds to the top-left panel of Figure 1. The orange curve depicts welfare with homogeneous industries—clearly, sensitivity to merger policy is very much diminished. As Table 9 in Appendix B.4 shows, both the value and rate of mergers are also much lower with homogeneous industries.

1.3 Comparison with the Literature

A large literature looks at merger policy from a static viewpoint;[17] only few papers take a dynamic view. Federico (2017) lays groundwork and Federico et al. (2018) provides a general, insightful two-period study of mergers and innovation. Gowrisankaran (1999) and more recently Marshall and Parra (2016), Mermelstein et al. (2020) and Bourreau et al. (2024) derive partial-equilibrium models of mergers, innovation and policy, and Igami and Uetake (2020) and Yao (2020) introduce early dynamic general equilibrium models with mergers. David (2021) develops a model of endogenous mergers in general equilibrium assuming perfect competition, where firms allocate effort to search for synergistic merger opportunities. In our imperfectly competitive model, mergers have some inherent social value even without cost synergies: they reduce wasteful duplication of research effort and encourage entry by increasing the value of incumbency.

[16] For monopoly to be well defined, we assumed that home production was possible at a cost commensurate with the monopoly markups of our main calibration, pinning down monopoly prices; see Appendix B.4.

[17] A recent prominent example is Nocke and Whinston (2022); see also references therein.

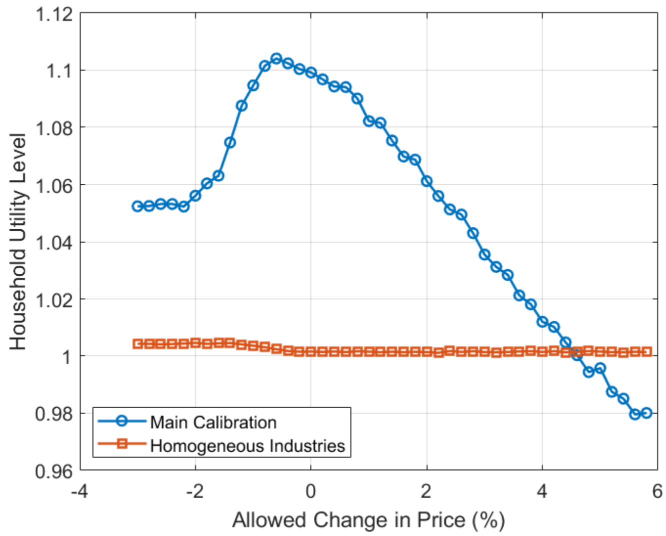

Figure 2: Welfare with different Δp thresholds in our model compared to homogeneous industries.

As discussed, we extend models of innovation based on quality ladders (Footnote 12) by developing a richer framework with interacting industry heterogeneity. The closest papers in this literature are Fons-Rosen et al. (2023), who focus on start-up acquisitions and stay away from comprehensive merger policy, and Cavenaile et al. (2021), who study merger policy in a quality-ladder framework. Our model, quantitative results, and economic mechanisms are notably richer and significantly different from those in Cavenaile et al. (2021). Unlike our paper, they estimate a very modest social value of antitrust: long-run growth decreases by 2 basis points (b.p.) from their status quo to having no antitrust authority, and their merger rate increases by 2 b.p. Instead, as Table 1 shows, our merger rate changes by more than 700 b.p. and growth decreases by 25 b.p., so our welfare change is orders of magnitude greater.[18] Their assumptions imply very low merger gains, in contrast with other estimates like David (2021), hence low merger incentives and policy sensitivity. Still, we agree with Cavenaile et al. (2021) that dynamic welfare effects of antitrust are much larger than static ones.

Finally, based on the concept that knowledge spillovers across firms generate virtuous productivity growth from Guthmann and Rahman (2025), which we find quantitatively significant, we model firms innovating continuously over time—productivity processes are Brownian, with drifts that depend on investment and rank.[19] This extends discrete-Poisson models based on Aghion et al. (1997, 2005) and Lucas and Moll (2014), with rich innovation dynamics.

[18] This is partly due to having homogeneous industries, as Figure 2 illustrates (see also Appendix B.4), and their assumption that an antitrust authority's merger acceptance probability is 99.1%, which obviates the need for a merger authority (without which the acceptance rate would be 100%). Their estimate is obtained by matching merger acceptances to merger applications, which ignores merger opportunities that were not submitted for consideration, and therefore overestimates—we think greatly—the authority's acceptance rate.

[19] Thus, as developed in Section 2, laggards tend to grow faster than the productivity leader, all else equal. For more on such rank-dependent diffusions, see Fernholz (2002) and Fernholz et al. (2013).

2 Model

Time is continuous, indexed by $t \geq 0$. A representative household in this economy consumes a continuum of good varieties indexed by $j \in [0,1]$ over time. For each good variety j, a finite set I_{jt} of firms can produce the variety at time t, with labor as their only input. The household supplies labor to firms and exerts entrepreneurial effort, which leads to the creation of new firms with better technology than that of incumbent firms. In this section, we describe this economy in detail. We begin by describing households, followed by firms.

2.1 Representative Household

The representative household's utility function is a present discounted value

$$\int_0^\infty e^{-rt} U(c_t, e_t, \ell_t | Y_t) \mathrm{d}t$$

of utility flows $U(c_t, e_t, \ell_t | Y_t)$ with discount rate $r > 0$, where $c_t = (c_{jt})_{j \in [0,1]} \geq 0$ denotes the consumption bundle, $\ell_t \geq 0$ denotes labor supplied, $e_t \geq 0$ denotes entrepreneurial effort, and $Y_t \geq 0$ denotes aggregate output at each time t. The household's flow utility function equals

$$U(c_t, e_t, \ell_t | Y_t) = \left(\int_0^1 c_{jt}^{\frac{s-1}{s}} \mathrm{d}j \right)^{\frac{s}{s-1}} - h(e_t, \ell_t) \times Y_t, \tag{1}$$

where $s > 1$ is the constant elasticity of substitution across varieties and $h(e_t, \ell_t)$ describes the disutility of entrepreneurial effort and labor.[20] Specifically, given a 'Frisch elasticity' $\psi > 0$,

$$h(e_t, \ell_t) = (e_t)^{1+\frac{1}{\psi}} + (\ell_t)^{1+\frac{1}{\psi}}.$$

Thus, $h(e_t, \ell_t)$ is a strictly increasing, convex function of entrepreneurial effort and labor.[21] It is multiplied by the aggregate output Y_t in (1) above to ensure that the opportunity costs of effort and labor grow in tandem with the economy.[22]

Let $\|c_t\| = (\int_0^1 c_{jt}^{\frac{s-1}{s}} \mathrm{d}j)^{\frac{s}{s-1}}$ be the CES aggregate of good varieties at time t, which we use as the economy's numeraire. Specifically, given prices $p_t = (p_{jt})$ for good varieties, we assume without loss of generality that $\int_0^1 p_{jt}^{1-s} \mathrm{d}j = 1$ at each time t. This assumption leads to the following simple form for household demand.

[20] Utility is linear in the 'composite good' $(\int_0^1 c_{jt})^{\frac{s-1}{s}}$ in order to simplify the calculation of consumption-equivalent welfare. Still, our model is close to the typical assumption of log utility in the literature, where consumption times marginal disutility of labor equals the wage. In our model, output times marginal disutility equals the wage. Since output and consumption grow together, the two models are qualitatively equivalent.

[21] Note that the disutility function above is assumed to be separable in labor and entrepreneurial effort. This facilitates having two different household types in our model—entrepreneurs and workers—to evaluate the distributional impact of merger policies. Thus, entrepreneurial households may benefit from higher markups, with the associated decrease in labor's share of income hurting working class households; see Section 5.4.

[22] This assumption is discussed at length in our calibration section. Its purpose is to ensure that effort and labor supply neither explode to infinity nor implode to zero in the long run.

Lemma 1. *Given prices $p_t = (p_{jt})$ for good varieties and income flow y_t at time t, the household's budget problem yields constant-elasticity demand curves*

$$c_j(p_t, y_t) = \frac{y_t}{p_{jt}^s}. \tag{2}$$

Since there are no asset markets, the household is unable to save or borrow. Thus, household income flow y_t at time t equals aggregate consumption $\|c_t\|$ and aggregate output Y_t, since the household owns all firms and earns all of labor's wages, and the aggregate output price $(\int_0^1 p_{jt}^{1-s}\mathrm{d}j)^{\frac{1}{1-s}}$ is normalized to 1.

2.2 Firm Production

Each variety $j \in [0, 1]$ can be produced by a set of firms I_{jt} at time t, called the jth industry; let $N_{jt} = |I_{jt}|$ be the number of such firms. Such firms compete in quantities: their production plans result from Cournot competition. Every firm $i \in I_{jt}$ uses a linear technology: it converts each unit of labor into $\exp(Z_{it})$ units of variety j, where Z_{it} is firm i's log-productivity at time t. Given a wage rate w_t, therefore, firm i's marginal cost of production at time t is

$$\gamma_{it} = \frac{w_t}{\exp(Z_{it})}.$$

Let $q_{jt} = (q_{it})_{i\in I_{jt}}$ be the vector of quantities produced by each firm $i \in I_{jt}$ and $Q_{jt} = \sum_{i\in I_{jt}} q_{it}$ the total amount of variety j produced at time t. Inverting the demand curve of Lemma 1 yields a *net revenue* flow for firm i in industry j of

$$R_{it}(q_{jt}) = (p_{jt} - \gamma_{it})q_{it} = \left[\left(\frac{y_t}{Q_{jt}}\right)^{\frac{1}{s}} - \gamma_{it}\right] q_{it}.$$

In line with the literature, we assume that every firm in each industry plays a Markov perfect equilibrium:[23] for each $i \in I_{jt}$, letting $q_{-ijt} = (q_{kt})_{k\in I_{jt}, k\neq i}$ be the output profile of every firm in industry j except for i at time t, the output profile $q_{jt}^* = (q_{it}^*)_{i\in I_{jt}}$ satisfies

$$q_{it}^* \in \arg\max_{q\geq 0} R_{it}(q, q_{-ijt}).$$

Let $R_{jt}^* = (R_{it}(q_{jt}^*))_{i\in I_{jt}}$ denote the profile of net revenue flows in equilibrium.

Lemma 2. *For each $i \in I_{jt}$ with $q_{it}^* > 0$, firm i's equilibrium market share satisfies*

$$\frac{q_{it}^*}{Q_{jt}^*} = s\left[1 - \frac{\gamma_{it}}{\Gamma_{jt}^*}\left(|I_{jt}^*| - \tfrac{1}{s}\right)\right],$$

where I_{jt}^* is the set of firms $k \in I_{jt}$ with $q_{kt}^* > 0$ and $\Gamma_{jt}^* = \sum_{k\in I_{jt}^*} \gamma_{it}$.

[23] Otherwise, an industry could be open to repeated-game collusive equilibria, with firms acting as a single monopolist (e.g., Rahman, 2014). Since collusion is a different (and illegal) antitrust phenomenon, we assume it away by restricting attention to Markov perfect equilibria to focus on merger policy for competing oligopolists.

2.3 Technological Progress from Symbiotic Competition

Let us describe how incumbent firms grow. We assume firms' log-productivity in an industry evolves over time driven by two forces: innovation investment and knowledge spillovers, which we dub 'symbiotic competition' like in Guthmann and Rahman (2025), as follows.

Assumption 1. For each industry j, the profile $Z_{jt} = (Z_{it})_{i \in I_{jt}}$ of log-productivity across its firms is a stochastic process, independent of other industries, with law

$$\mathrm{d}Z_{it} = \begin{cases} (\mu_{it} + \theta)\mathrm{d}t + \sigma \mathrm{d}W_{it} & \text{if } Z_{it} < \max\{Z_{kt}\}_{k \in I_{jt}} \text{ and} \\ \mu_{it}\mathrm{d}t + \sigma \mathrm{d}W_{it} & \text{if } Z_{it} \geq \max\{Z_{kt}\}_{k \in I_{jt}}, \end{cases} \tag{3}$$

where $\theta, \sigma > 0$ are exogenous, $(W_{it})_{i \in I_{jt}}$ are independent Wiener processes, and μ_{it} is an endogenous variable resulting from investment in innovation.[24]

Assumption 1 says that each firm's log-productivity faces independent Brownian fluctuations, and its drift has both an endogenous component μ_{it} and an exogenous one, θ. We describe each in turn below. Broadly, μ_{it} is chosen by each firm i at each time t to equate a labor cost with the lifetime benefits of becoming more productive. On the other hand, θ captures knowledge spillovers from productivity leaders. In industries with several competing firms, each firm learns from and catches up to jointly determined best practices. As firms overtake one another in terms of productivity, they tend to pull up their competitors' productivity, too. Thus, average productivity has a tendency to grow faster than under monopoly.[25]

2.3.1 Innovation Investment

In addition to production decisions, q_{it}, firms also make investment decisions in continuous time. These investments are described by μ_{it} in (3) above, the drift of productivity (excluding knowledge spillovers, discussed in Section 2.3.2 below).

Firms' choice of μ_{it} is modeled as follows. Suppose that each firm i continuously chooses how much labor $\ell_{it}^r \geq 0$ to employ for researching ways of improving productivity. If ℓ_{it}^p is the amount of labor employed to produce i's output, $\ell_{it} = \ell_{it}^p + \ell_{it}^r$ is i's total labor employed. Given this choice, i's productivity Z_i follows the law of motion (3) above with drift parameter

$$\mu_{it} = (2\eta \ell_{it}^r)^{1/2},$$

where $\eta > 0$ describes how research translates into productivity improvements. This formulation says that there are diminishing marginal returns with respect to labor-for-research. When ℓ_{it}^r is close to zero, the marginal gain in μ_{it} from research increases without bound. Moreover,

[24] Thus, firms' productivity rates are diffusions with rank-based characteristics. For more on rank-dependent diffusions, see Fernholz (2002) and Fernholz et al. (2013).

[25] In Section 6 of Guthmann and Rahman (2025), we provide a discussion that explains why monopolists would not be able to replicate this symbiotic competition "technology."

as ℓ^r_{it} grows, the marginal gain in μ_{it} diminishes enough to effectively put an (endogenous) upper bound on the growth rate μ_{it} of a firm. Together, these results guarantee the existence of an interior solution to a firm's investment problem. As will be seen, an especially useful implication of this formulation is that the marginal cost of μ_{it} is linear. Indeed, inverting the drift yields $\ell^r_{it}(\mu_{it}) = \mu^2_{it}/(2\eta)$, so each firm's wage bill $w_t\ell^r_{it}$ has derivative $w_t\mu_{it}/\eta$. Let

$$\Pi_{it} = R_{it} - w_t\mu^2_{it}/(2\eta)$$

be each firm i's *profit flow* including investment flow costs. Each firm i chooses μ_{it}, together with q_{it}, in Markov perfect equilibrium, with μ_{it} determined by a system of HJB equations detailed in Section 3.2. For preview and intuition, equilibrium investment μ_{it} equates its marginal cost $w_t\mu_{it}/\eta$ to its marginal benefit V_{it,Z_i}, i.e., the marginal increase in firm i's present value profit at time t from an increase in own productivity Z_i. Rearranging,

$$\mu_{it} = \frac{\eta V_{it,Z_i}}{w_t}; \tag{4}$$

innovation investment decreases with wages and increases with marginal benefit, all else equal.

2.3.2 Symbiotic Productivity Growth

Our model of productivity co-evolution (3) includes spillovers. The drift in a firm's log-productivity depends on whether it is a productivity leader—laggard growth rates are faster by $\theta > 0$, all else equal. Eventually, a laggard catches up and becomes the new leader whose innovations are, in turn, absorbed by others. This adds to growth, as shown next.

Proposition 1 (Average productivity growth)**.** *Average productivity in industry j at time t, denoted by $X_{jt} = \sum_{k\in I_{jt}} Z_{kt}/N_{jt}$, obeys the law of motion*

$$\mathrm{d}X_{jt} = \left(\bar{\mu}_{jt} + \tfrac{N_{jt}-1}{N_{jt}}\,\theta\right)\mathrm{d}t + \tfrac{1}{\sqrt{N_{jt}}}\,\sigma\,\mathrm{d}W_{jt},$$

where $W_{jt} = \sum_{k\in I_{jt}} W_{kt}/\sqrt{N_{jt}}$ is a Wiener process and $\bar{\mu}_{jt} = \sum_{k\in I_{jt}} \mu_{kt}/N_{jt}$.

By Proposition 1, the drift of average log-productivity has two parts: an average endogenous component $\bar{\mu}_{jt}$, and an exogenous symbiotic component $\frac{N_{jt}-1}{N_{jt}}\theta$. This second component asymptotes to θ as N_{jt} increases without bound. Therefore, as the number of firms increases, spillovers push average productivity upwards, with diminishing returns in N_{jt}. Moreover, volatility of average productivity diminishes slowly (at rate $N^{-1/2}_{jt}$). Thus, industries with more firms tend to grow more and together, although the gains from symbiotic competition diminish with industry size in this parametrization.[26] Figure 3 below has an illustration.

[26]This is consistent with a large body of empirical literature. Porter (1990), Blundell et al. (1999), Syverson (2004), Bloom and Van Reenen (2007), Hashmi and Biesebroeck (2016), Igami and Uetake (2020) and Bhattacharya (2021) find a positive relationship, with varying confidence, between competition and productivity growth; see also Griffith and Van Reenen (2021).

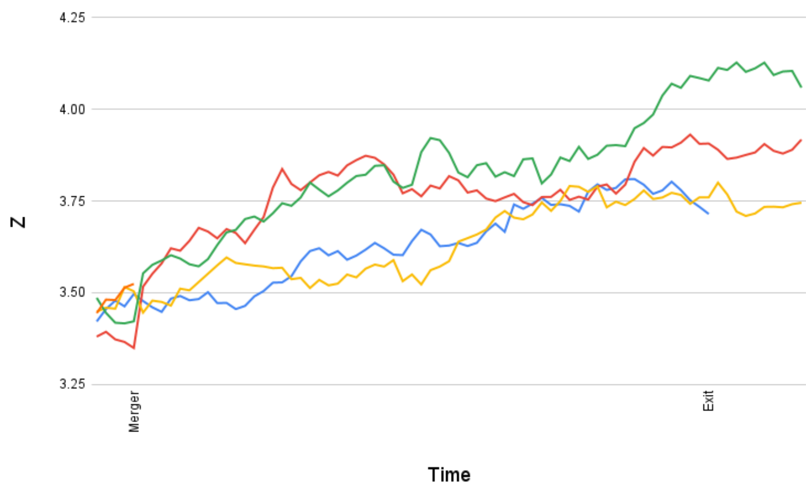

Figure 3: Sample paths of log-productivity for firms in an industry: Starting with 5 firms, the firms represented by the red and orange lines merge, and the red line becomes the merged entity's productivity path. Later, the firm represented by the blue line exits.

2.4 Firm Entry and Exit

Regarding exit, each firm i has a calibrated opportunity cost V_{it}^0 of operating in its industry. A firm exits if its value of staying in the industry, V_{it}, falls below this opportunity cost.

Entry of new firms is determined by households' entrepreneurial effort. When this effort results in the creation of a new firm i at time t, this new firm enters an industry $j \in [0, 1]$ with a linear technology and log-productivity Z_{it} that thereafter evolves according to (3). New firms are created by the household as a function of entrepreneurial effort e according to $F(e) = \delta e$, where $F(e)$ denotes the mass of new firms created when the representative household expends e units of entrepreneurial effort and $\delta > 0$ denotes its productivity. The industry j that a new firm i enters at time t is distributed IID uniformly on $[0, 1]$.

New firms enter markets with a random initial productivity that may be related to both the industry's log-productivity average and that of the whole economy. When new firm i enters market j at time t, its initial log-productivity is given by

$$Z_{it} = a + b\bar{Z}_t + (1 - b)\bar{Z}_{jt}^{-i},$$

where a is an IID random variable, $b \in [0, 1]$ is the weight of industry-wide average log-productivity $\bar{Z}_t = \int_0^1 \bar{Z}_{jt} dj$ just before time t and $\bar{Z}_{jt}^{-i} = \sum_{k \in I_{jt} \setminus \{i\}} Z_{kt}/(N_{jt} - 1)$ is the corresponding average within industry j excluding the new entrant i. The random variable a is assumed IID across firms. Its CDF, denoted by G, is calibrated in Section 4. This assumption parametrizes how start-ups contribute to productivity growth and it is harder to enter industries with more developed technology. Note that a need not be positive to improve overall productivity, since firms can enter industries with lower than average productivity.

The weight b can be interpreted as controlling endogenous barriers to entry. If $b = 0$, new entrants enter each industry with its average productivity, so they can compete with firms subject to their draw of a. As b increases, new entrants find it more difficult to compete in highly productive industries and easier to compete in less productive ones. In this sense, an industry with higher productivity deters entry. If $b < 0$ then higher-productivity industries would instead *attract* more productive entry. This might capture entry directed towards profitable industries, say. This is an interesting theoretical possibility, but our calibration implies $b > 0$, i.e., the data suggest that productivity deters entry rather than invite it.

2.5 Mergers

We model mergers as follows. Assume that mergers are horizontal and voluntary. Each firm operates in only one industry and chooses whether to merge with another firm in its industry whenever the opportunity arises. A merging opportunity between two firms is brought by a 'Calvo' process, that is, it arrives at a random time, at which point firms decide whether to forego the opportunity or take it, subject to the government allowing the merger to proceed. We go over these details below, including merger negotiations and government policy.

2.5.1 Synergies and Frictions

Let i_1 and i_2 be two firms in a given industry j that merge at time t to form a new firm $m = \{i_1, i_2\}$. We assume that m has access to the merged firms' market-share weighted technology plus a random cost reduction, that is,

$$\gamma_{mt} = (1 - S)\left[\gamma_{i_1 t}\frac{q_{i_1 t}}{q_{i_1 t} + q_{i_2 t}} + \gamma_{i_2 t}\frac{q_{i_2 t}}{q_{i_1 t} + q_{i_2 t}}\right],$$

where $S \geq 0$ is the merger's *cost synergy* and $q_{i_1 t}, q_{i_2 t}$ denote the pre-merger output choices of firms i_1 and i_2 at time t.[27] The distribution of S is discussed in Section 4.

If arbitrarily many firms were able to merge at any time, they would immediately do so to form a monopoly, as long as the resulting firm had a weakly better technology than pre-merger firms, since monopoly profits would be strictly greater. To avoid this implication, we introduce merger frictions: merger opportunities follow a Poisson process in each industry, and opportunities cannot be stored, i.e., if a merger opportunity is not carried out, it is lost. Specifically, in every industry j with two or more firms, for every pair of firms i_1 and i_2 in I_{jt}, at every time t, a merger opportunity between them arrives with probability $\lambda \mathrm{d}t$. This matching probability is independent across firm pairs and time in each industry. We further discuss the parameter λ when we come to our calibration in Section 4.

[27] If both $q_{i_1 t}$ and $q_{i_2 t}$ equal zero, we assume that γ_{mt} is the unweighted average of $\gamma_{i_1 t}$ and $\gamma_{i_2 t}$.

2.5.2 Merger Policies

In a static economy, mergers must increase output to increase consumer surplus (Nocke and Whinston, 2010). But for output to increase, post-merger marginal costs must be so much lower than those pre-merger that implied merger synergies could become unrealistically high. In our dynamic model, output need not increase immediately after a welfare-enhancing merger. On the one hand, a merger reduces the number of firms, hence the intensity of competition, increasing markups and reducing symbiotic productivity growth. On the other hand, higher profits from mergers increase the value of new firms: there is a chance that they will enter as productivity leaders in an industry and benefit from merging with less productive competitors, essentially removing them. This motivates entrepreneurial effort, which raises productivity growth in each industry via innovation through entry. Thus, merger policy ought to allow some mergers to occur but not so many that welfare losses from foregone symbiotic productivity growth and higher markups due to increased market power exceed static synergy gains and dynamic benefits from firms' innovation incentives.

By a merger policy, we mean a rule that authorizes which mergers proposed by firms seeking to merge can take place. We consider the following kinds of merger policies:

1. $N_{\min}$ **Rule.** The anti-trust authority blocks all mergers that lead to fewer than $N_{\min}$ firms operating in the industry.
2. **HHI Rule.** The anti-trust authority blocks a merger if the industry's post-merger HHI score is higher than a prespecified threshold.
3. **ΔHHI Rule.** The anti-trust authority blocks any merger that would result in a change in an industry's HHI score beyond a prespecified threshold.
4. Δp **Rule.** The anti-trust authority blocks any merger that would increase an industry's post-merger price beyond a prespecified threshold.
5. $\alpha\beta$ **Policy.** Given parameters α and β, the antitrust authority blocks a merger in an industry j if it increases the industry's log price above the threshold

$$\alpha + \beta(\bar{Z}_{jt} - \bar{Z}_t),$$

   where $\bar{Z}_{jt} = \sum_{k \in I_{ij}} Z_{kt}/N_{jt}$. Thus, mergers are authorized if they increase prices by a percentage smaller than α plus an adjustment for relative industry productivity.

The $N_{\min}$ rule above is perhaps the simplest and most transparent, whereas the HHI and ΔHHI rules—and combinations thereof, like the 2023 Merger Guidelines discussed later—are more common in policy circles (see, e.g., Nocke and Whinston, 2010). The Δp rule above is a simple policy that effectively bounds post-merger price increases. If the industry becomes more concentrated and markups rise, a merger is only authorized if firms' costs decrease enough that the increase in prices is smaller than the prespecified threshold.

An $\alpha\beta$ policy is slightly more sophisticated than the Δp rule, by taking into account an industry's average productivity relative to the economy average. The motivation for this policy is that if $b > 0$ then industries with higher than average productivity feature entry barriers that make it more difficult for new firms to establish themselves, as their initial productivity can be much smaller than the industry's average. An $\alpha\beta$ rule with $\beta < 0$ allows merger policy to be more strict for industries with significant—even if endogenous—entry barriers. At the same time, merger policy with $\beta < 0$ is more lax in industries whose productivity is below average. This encourages entry of productive firms into less productive industries, which generates endogenous productivity growth.

The price policies above reflect a trade-off between lower residual demand elasticity pushing up prices and cost synergies lowering them post-merger that is often at the heart of legal merger cases.[28] In practice, many variables are difficult to measure; in this model, we assume that synergies are observable and post-merger industry prices predictable.

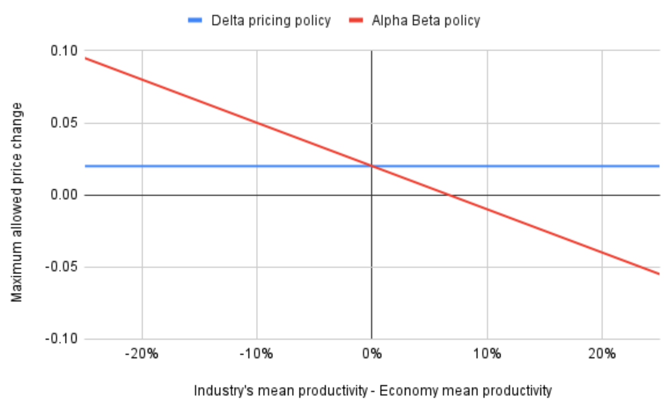

Figure 4: Maximum allowed change in prices in a Δ pricing rule (blue) and in an $\alpha\beta$ policy (red) as a function of the industry's productivity relative to the economy.

2.5.3 Merger Negotiations

Next, we discuss how firms in our model negotiate a merger. Given a merger policy as above, suppose firms i_1 and i_2 obtain a merger opportunity at time t that would be authorized by the anti-trust authority. We assume that the value of a merged firm is apportioned between the merging firms according to Nash bargaining. Specifically, for each i in $m = \{i_1, i_2\}$, let V_{it} be the expected present value of operating in the industry without the merger opportunity, and V_{mt} denote the present value of the merged firm at time t.[29] The value from this merger opportunity V_{mt} is divided between firms i_1 and i_2 according to the symmetric Nash bargaining solution,[30] with disagreement point given by V_{i_1t} and V_{i_2t} for firms i_1 and i_2, respectively.

[28] See, e.g., FTC v. Staples, Inc. (1997) and FTC v. Staples, Inc. (2016), among many others.
[29] Subsequent mergers are assumed to be negotiated via Nash bargaining in the same way.
[30] Our calibrated results are quantitatively robust to changes in bargaining weights; see Appendix B.2.

Therefore, when a merger goes through, firm i's value becomes

$$V_{it} + \frac{1}{2}[V_{mt} - (V_{i_1t} + V_{i_2t})]$$

assuming $V_{mt} \geq V_{i_1t}+V_{i_2t}$, otherwise the merger opportunity is discarded. The value functions above and their HJB equations are fleshed out in Section 3.2.

3 Equilibrium

In this section we define equilibrium. We begin by providing a conceptual definition, followed by a more detailed description of each of its components.

Definition 1. An *equilibrium* consists of prices, quantities, investments $(p_{jt}, q_{it}, \mu_{it})$ for each industry and firm over time,[31] blueprint prices v_t, wages w_t, effort e_t and labor ℓ_t so that

1. The representative household chooses consumption, effort and labor (c_t, e_t, ℓ_t) to maximize lifetime utility subject to a budget constraint whose income is determined by dividends from existing firm profits, blueprints δe_t times the value v_t of new firms, and labor ℓ_t times wages w_t. (See Section 3.1.)
2. In every industry, firms compete in quantities à la Cournot and invest in productivity by choosing (q_{it}, μ_{it}) to maximize their present value profit given other firms' strategies, as well as the representative household's demand. Their strategies constitute a Markov perfect equilibrium. (See Section 3.2.)
3. Firm entry rates are determined by the household's choice of entrepreneurial effort. Firms' exit decisions are consistent with the exit rule above.
4. All merger opportunities that arise over time are accepted or rejected in accordance with the anti-trust authority's merger policy as well as the profitability of the merger to the merging firms in present value terms, with merger surplus allocated to firms according to the symmetric Nash bargaining solution.
5. All goods markets as well as the blueprint and labor markets clear.

Existence of the equilibrium above is straightforward.[32] Such an equilibrium is called a *balanced growth path* (BGP) if its output y_t grows at a constant rate.

Proposition 2. *A BGP exists, is unique, and exhibits positive entrepreneurial effort.*

We now describe each component of the equilibrium above in detail.

[31] The composite good is used as numeraire; without loss, its price is normalized to 1 for all t.

[32] Existence of Nash equilibrium under Cournot competition with firms exhibiting constant marginal costs is standard. Given such firm behavior, expected income from both labor and entrepreneurship is well defined. This implies that the choice of labor supply and blueprint production by households is well defined, too. Finally, equilibrium with investment into productivity exists assuming that marginal returns diminish to zero.

3.1 Household Income

Let us formalize the household's budget problem to account for firm profits. In Lemma 1, the representative household's budget problem was solved for a given level of overall income to obtain its demand for consumption goods; this was without loss because consumption utility and effort/labor costs are separable. There, household demand for each variety $j \in [0, 1]$ depends on its price p_{jt} and household income, which equals aggregate output y_t.

Aggregate output is converted into two income sources: profits from firms and wages, thus

$$y_t = \Pi_t + w_t \ell_t,$$

where Π_t is the aggregate profit flow from firms:

$$\Pi_t = \int_0^1 \sum_{i \in I_{jt}} \Pi_{it} \mathrm{d}j.$$

We incorporate entrepreneurship and entrepreneurial effort into our model by adding and subtracting the value of new firms into the household's budget constraint, as follows. Let v_t be the expected present discounted value of a new firm, and δe_t the flow of new firms as a result of entrepreneurial effort from Section 2.4. The value v_t is the price of a start-up firm, i.e., the expected discounted value of a firm at birth. We assume that an individual household's budget incorporates the return on their entrepreneurial effort as follows:

$$y_t = v_t \delta e_t + \Delta_t + w_t \ell_t,$$

where Δ_t is the difference between the value of new firms times the number of new firms created ($v_t \delta e_t$) and the aggregate profit flow (Π_t) at a point in time t, that is, $\Delta_t = \Pi_t - v_t \delta e_t$. Specifically, there is a continuum of risk-neutral intermediary firms, owned by households, that buy entrepreneurs' blueprints at a market price of v_t and turn them into producing firms that pay profit flows as dividends to shareholders. Both intermediary and producing firms make zero expected present value profit. Households do not internalize the general equilibrium effects of creating new firms on their budget constraint, e.g., creating new firms can lower markups by increasing competition, thus lowering Π_t. In equilibrium, households choose their effort e_t by comparing marginal cost, $h'_e(e_t)$, with marginal benefit, $v_t \delta$.

3.2 Firms' Value Functions

The value V_{it} of a firm i is the expected present value of equilibrium current and future profit flows. It evolves according to several state variables and choices depicted below. First, firm i chooses a quantity to produce, q_{it}, and investment in innovation at the intensive margin, μ_{it}. In addition, it may face the arrival of discrete events such as entry, own exit as well as exit and mergers by other firms, and must decide whether to merge with another firm should the opportunity arise. Our goal in this subsection is to pin down the law of motion of V_{it}.

We begin by describing the evolving state of the economy. At every time $t \geq 0$, each industry $j \in [0,1]$ consists of its set of firms I_{jt} and the log-productivity profile $Z_{jt} = (Z_{it})_{i \in I_{jt}}$, where Z_{it} evolves according to (3). If $I_t = (I_{jt})_{j \in [0,1]}$ and $Z_t = (Z_{jt})_{j \in [0,1]}$, the aggregate state of the economy is (I_t, Z_t). Given this aggregate state, all aggregate variables are implied by a heuristic law of large numbers for the continuum of industries in this economy. In particular, aggregate output y_t, wages w_t and entrepreneurial effort e_t evolve deterministically over time in the BGP. Thus, we will write the expected discounted value of each firm $i \in I_{jt}$ in industry j at time t interchangeably as V_{it} and $V_i(I_{jt}, Z_{jt})$, taking as given and leaving implicit the dependence of a firm's present value on the path of aggregate economic variables.

The law of motion associated with each firm's value function is presented next. Every time $t \geq 0$ consists of two 'halves.' In the first half, firms who meet the exit threshold exit. Given the state (I_{jt}, Z_{jt}) at time t, let $\hat{I}_{jt} = \{i \in I_{jt} : V_{it} > V_{it}^0\}$ be the set of firms who do not exit in the first half of time t, where V_{it}^0 is i's outside option value (assumed dependent on the same states as V_{it}). Every firm $i \in I_{jt} \setminus \hat{I}_{jt}$ exits at time t, Once a firm exits, it does so permanently; more than one firm may exit at a time. In the second half of t, each firm i in $\hat{I}_{jt}$ chooses a vector (q_{it}, μ_{it}) of quantities and innovation investment in Markov perfect equilibrium. Moreover, entry and mergers may take place, so that, for every industry j, the set I_{jt} evolves in line with the assumptions stipulated in our model of Section 2 and $\hat{Z}_{jt} = (Z_{it})_{i \in \hat{I}_{jt}}$ evolves according to (3). Let I'_{jt} be the set of firms in industry j at the end of the second half of period t. A firm i belongs to I'_{jt} if either (a) it was there in the first half of of t and neither exited nor merged, (b) it just entered industry j, (c) it is the merged entity resulting from a merger that just took place. Entry and merger opportunities follow independent Poisson processes, so almost surely at most one of these occurs at a time.

First, let $\hat{V}_{it} = V_i(\hat{I}_{jt}, \hat{Z}_{jt})$ be the value of firm i at the end of the first half of t. Firm i chooses q_{it} to maximize $\hat{\Pi}_{it} = \Pi_i(\hat{I}_{jt}, \hat{Z}_{jt})$, the net profit flow of firm i when the state of industry j is $(\hat{I}_{jt}, \hat{Z}_{jt})$. By definition of $\hat{I}_{jt}$ and continuity, firms' log-productivity profile $\hat{Z}_{jt}$ lies in the interior of the set of values where no firm in $\hat{I}_{jt}$ wishes to exit. Therefore, absent entry or mergers, $\hat{V}_{it}$ is a diffusion process that depends on i's choice of μ_{it} and the vector $\hat{Z}_{jt}$. Entry arrives at rate δe_t. In case of entry into industry j at time t, call the new entrant i'_t; the new set of firms becomes $I_{jt}^{\{i'_t\}} = \hat{I}_{jt} \cup \{i'_t\}$. The new entrant's initial draw of log-productivity equals $\hat{Z}_{i'_t t}$, with distribution described in Section 2. Prior to entry, $\hat{Z}_{i'_t t}$ is not known, so i takes its expectation. Let $E[V_i(I_{jt}^{\{i'_t\}}, \hat{Z}_{jt}, \hat{Z}_{i'_t t})|\hat{Z}_{jt}]$, or $E[V_{it}^{\{i'_t\}}|\hat{Z}_{jt}]$, for short, be the expected value of firm $i \in \hat{I}_{jt}$ with respect to $\hat{Z}_{i'_t t}$ when i'_t enters industry j at time t.

Every pair of firms in $\hat{I}_{jt}$ may find a merger opportunity with independent arrival rate λ. Given a pair of firms $k, k' \in \hat{I}_{jt}$, suppose that k and k' merge to form the new entity $\{k, k'\}$. Let $I_{jt}^{\{k,k'\}} = \{\{k,k'\}\} \cup \hat{I}_{jt} \setminus (\{k\} \cup \{k'\})$ be the set of firms resulting from the replacement of k

and k' with their merged entity $\{k, k'\}$. Let $Z_{jt}^{\{k,k'\}}$ be the log-productivity profile in industry j with firm set $I_{jt}^{\{k,k'\}}$ and $Z_{\{k,k'\}t}$ as the realized initial draw of log-productivity for the newly merged entity $\{k, k'\}$, distributed as described in Section 2. Let $V_{it}^{\{k,k'\}} = V_i(I_{jt}^{\{k,k'\}}, Z_{jt}^{\{k,k'\}})$ be the value of i when k and k' merge, and $E[V_{it}^{\{k,k'\}}|\hat{Z}_{jt}]$ its expectation over $Z_{jt}^{\{k,k'\}}$.

Consider a firm $i \in \hat{I}_{jt}$. If i receives the opportunity to merge with firm k, recall that, by assumption, the merger goes through if the merger authority approves it and $V_{\{i,k\}t}^{\{i,k\}} \geq \hat{V}_{it} + \hat{V}_{kt}$. In this case, firm i's Nash-bargaining payoff is $\hat{V}_{it} + \frac{1}{2}[V_{\{i,k\}t}^{\{i,k\}} - (\hat{V}_{it} + \hat{V}_{kt})]$, since we assume symmetric bargaining power.[33] Therefore, the change in present value to firm i from a merger opportunity with k is the difference $\hat{V}_{it} + \frac{1}{2}[V_{\{i,k\}t}^{\{i,k\}} - (\hat{V}_{it} + \hat{V}_{kt})] - \hat{V}_{it} = \frac{1}{2}[V_{\{i,k\}t}^{\{i,k\}} - (\hat{V}_{it} + \hat{V}_{kt})]$. Let $\mathbf{1}_{jt}^{\{i,k,\}}$ be the indicator that the merger between firms i and k is both rational and legal, i.e., equal to 1 if the above inequality holds and the merger authority approves the merger and 0 otherwise. Taking expectations with respect to $Z_{jt}^{\{i,k\}}$, the change in value to i from the merger opportunity with k is $\frac{1}{2}E[(V_{\{i,k\}t}^{\{i,k\}} - (\hat{V}_{it} + \hat{V}_{kt}))\mathbf{1}_{jt}^{\{i,k\}}|\hat{Z}_{jt}]$.

Next, suppose that firms k and k', each different from i, obtain the merger opportunity. For firms k and k' to merge, it must be the case that $V_{\{k,k'\}t}^{\{k,k'\}} \geq \hat{V}_{kt} + \hat{V}_{k't}$. Let $\mathbf{1}_{jt}^{\{k,k'\}}$ be the indicator that the merger is rational and legal, i.e., equal to 1 if this inequality holds and the merger authority approves it and 0 otherwise. The change in value to firm i from the merger opportunity between k and k' is therefore $E[(V_{it}^{\{k,k'\}} - \hat{V}_{it})\mathbf{1}_{jt}^{\{k,k'\}}|\hat{Z}_{jt}]$.

Let us put this all together to describe the law of motion for a firm's value function.

Proposition 3. *With the above notation, the value of firm i in $\hat{I}_{jt}$ at time t satisfies*

$$r\hat{V}_{it} = \max_{(q_{it},\mu_{it})\geq 0} \hat{\Pi}_{it} + \sum_{k\in\hat{I}_{jt}} (\mu_{kt} + \theta\mathbf{1}_{jt}^{k})\frac{\partial \hat{V}_{it}}{\partial Z_k} + \tfrac{1}{2}\sigma^2\frac{\partial^2 \hat{V}_{it}}{\partial Z_k^2} + \delta e_t\big(E[V_{it}^{\{i'_t\}}|\hat{Z}_{jt}] - \hat{V}_{it}\big)$$
$$+ \lambda \sum_{k\in\hat{I}_{jt}\setminus\{i\}} \tfrac{1}{2}E[(V_{\{i,k\}t}^{\{i,k\}} - (\hat{V}_{it} + \hat{V}_{kt}))\mathbf{1}_{jt}^{\{i,k\}}|\hat{Z}_{jt}] + \tfrac{1}{2}\lambda \sum_{k,k'\in\hat{I}_{jt}\setminus\{i\}} E[(V_{it}^{\{k,k'\}} - \hat{V}_{it})\mathbf{1}_{jt}^{\{k,k'\}}|\hat{Z}_{jt}],$$

where $\mathbf{1}_{jt}^{k} = 0$ if firm k is a productivity leader in industry j at time t and 1 otherwise, and $V_{it} = \hat{V}_{it}$ if $i \in \hat{I}_{jt}$ and 0 otherwise.

The law of motion above reflects five factors that enter into a firm's value function: (i) profit flow, (ii) the diffusion of productivity, (iii) entry, (iv) own merger prospects, and (v) others' merger prospects. The HJB equation above is too complicated to solve analytically. Nevertheless, this HJB equation implies that an equilibrium choice of μ_{it} satisfies the first-order conditions of Section 2. This follows because $\hat{\Pi}_{it}$ is concave and $\mu_{it}\frac{\partial \hat{V}_{it}}{\partial Z_i}$ linear in μ_{it}, and no other term depends on μ_{it}. Our next goal is to solve the model computationally.

[33] In Appendix B.2 we consider different bargaining weights and show that the optimal Δp rule does not change significantly if we increase the Nash bargaining weight of the larger firm from 0.50 to 0.75.

4 Computation and Calibration

This section describes our numerical method for computing economic variables of the above model, as well as our calibration of parameters and targeted moments. Section 5 reports our analysis of merger policy with the calibrated model.

4.1 Computational Method

To computationally approximate our model of an economy with a continuum of industries in continuous time, we discretize time into quarters, and the continuum of industries into several thousand varieties. To find equilibrium, we (1) compute Markov perfect equilibrium quantities produced by firms in each industry at each quarter, and (2) for each industry at each quarter, find firms' optimal investments in innovation and compute their exit and merger decisions, and (3) given the estimated behavior of all firms, compute optimal levels of entrepreneurial effort and labor supply chosen by the representative household.

Computing (1) is a simple exercise of calculating Cournot equilibria. To compute (2), we estimate firms' value functions as follows. First, we compute the profit histories of firms operating in simulated industries as well as the present value of firms' lifetime profits. To circumvent the dimensionality curse when computing value functions, we regress firms' characteristics over our simulated sample of present values of firms to estimate their value functions.

Specifically, our computational method approximates each firm i's value function as follows. First, we partition the set of industries into four quartiles $Q \in \{1, 2, 3, 4\}$ according to the industry's mean productivity relative to all other industries. Then, for each quartile, we partition the industries of the economy into ten subsets depending on their number of firms: industries with $N_{jt} \in \{1, 2, 3, 4, 5, 6, 7, 8, 9\}$, and $N_{jt} \geq 10$. For an industry in productivity quartile Q with N_{jt} firms, we estimate V_{it} using the following polynomial fit, with firm value data generated by Monte Carlo simulations:

$$V_{it}^e = \alpha_{Q,N_{jt}} + \beta^1_{Q,N_{jt}}(Z_{it} - EZ_{jt}) + \beta^2_{Q,N_{jt}}(Z_{it} - EZ_{jt})^2 + \beta^3_{Q,N_{jt}}\text{Var}(Z_{-ijt}), \tag{5}$$

where the parameter $\alpha_{Q,N_{jt}}$ equals the expected value of firm i in industry j, $\beta^1_{Q,N_{jt}}$,$\beta^2_{Q,N}$ are parameters measuring the effect of a firms' relative productivity compared to the industry's mean, and $\beta^3_{Q,N_{jt}}$ measures the effect of variance in competitors' mean productivity.[34] Given these estimated value functions, we compute the model's equilibrium and draw a new history of profits for a sample of firms, which, in turn, induces new value function estimates. After several iterations, our parameter estimates converge to a fixed point.

[34] In Appendix B.3, we consider several variations of this procedure, and show that increasing the degree of the polynomial regression or the fineness of productivity quantiles does not change our results significantly.

To compute (3), we first define a grid of entrepreneurial efforts. Each point in that grid determines the rate at which firms are created. We simulate the economy at each point to compute the expected profitability of creating new firms. This expected profitability determines an optimal effort level in "response" to the level of effort at the point in the grid. The equilibrium level of effort is a fixed point where the response is equal to the imputed level of effort. To find it, we regress these best responses over the grid of effort levels, this delivers our fixed point of entrepreneurial effort, as shown in Figure 5 below. Note that the level of entrepreneurial effort determines the entry rate of firms, which affects their value function. To better approximate equilibrium value functions, we compute (3) at each iteration of the algorithm and estimate the parameters of the value function as described above.

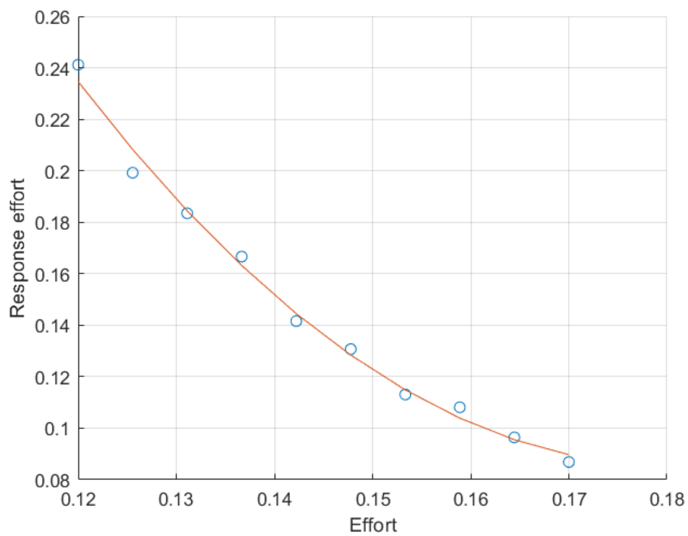

Figure 5: Equilibrium entrepreneurial effort: at a fixed point, effort and its best response coincide.

Our goal is to find and analyze properties of the economy while in its balanced growth path (BGP). To do so, we assume that every industry begins as a monopoly, with their technological parameter Z_{i0} equal to 1. Setting a fixed entry rate (determined by the entrepreneurial effort level), we simulate the evolution of industries until the distribution of industries by number of firms and relative productivity level reaches a stationary state. (Technically, within a negligible threshold.) At this point, we say that the economy has approached its BGP. As Figure 7 below suggests, convergence to the BGP is swift.

To summarize, the procedure we used to compute economic variables in the BGP is as follows. First, we guess parameters of the value function. With these parameters, we compute the corresponding BGP entrepreneurial effort level; given the effort level and value function of the previous iteration, we estimate new parameters for the value function. After several iterations, the parameters of the value function approximate its fixed point. Finally, we simulate the economy using these parameters to calculate equilibrium firm and household behavior.

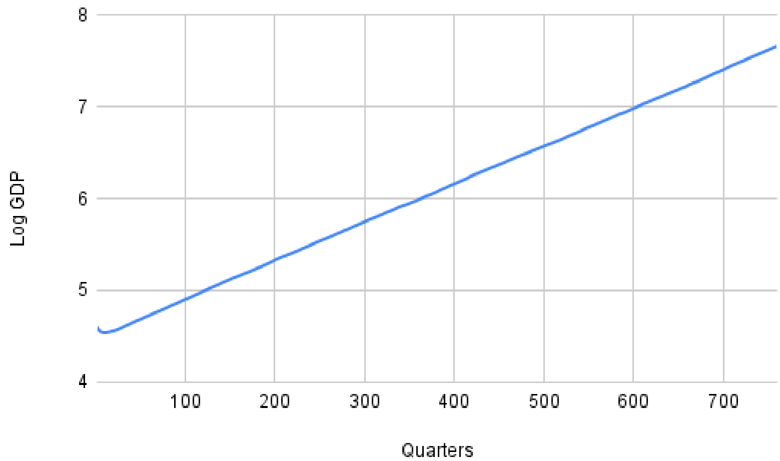

Figure 6: The economy's GDP time series suggests fast convergence to its balanced growth path.

4.2 Model Calibration

Table 3 below displays the parameters we used to calibrate our model. Regarding "externally calibrated" parameters, we took the Frisch elasticity of labor supply of 3 from Peterman (2016) and an annual discount rate of 4%, within the standard range for this parameter (typically between 2% and 5%). We took the substitution elasticity of demand for varieties, 1.75, to be the mean of substitution elasticities from Table 1 in Nocke and Whinston (2022). Our utility specification normalizes the household's multiplicative cost parameters of entrepreneurial effort and labor supply to 1,[35] since these parameters only affect output and effort levels without affecting the equilibrium's substantive properties. The Poisson arrival rate of merger opportunities is set at 2 per firm per year. Productivity spillovers are set to 1.2% based on Berlingieri et al. (2020), which, based on data from OECD countries, suggests a rate of productivity spillovers from leaders to followers around 1% to 1.5%. (I.e., the gap in productivity between followers and leaders tends to erode at a rate of ca. 1-1.5% per year.)

To reduce computational complexity, we approximated our assumption that firms exit if their value falls below V^0_{it} with a simpler exit rule, where each firm i exits the industry at time t if its marginal cost γ_{it} becomes greater than $1+\varepsilon_i > 1$ times the Cournot market price $p_t(Z_{jt})$. The exit tolerance parameter ε_i, calibrated to be 2.5%, corresponds to i's opportunity cost of staying in the industry. In our simulations, we found that an opportunity cost for firms V^0_{it} defined by industry productivity quartile, so $V^0_{it} = V^0_{Q_t}$ for productivity quartile $Q_t \in \{1, 2, 3, 4\}$, as $(V^0_1, V^0_2, V^0_3, V^0_4) = (0, 0.15, 0.30, 0.45)$, produced approximately the same exit rates per industry quartile as using the constant exit tolerance parameter $\varepsilon_i = 2.5\%$ for all firms. This is consistent with an average exit rate of ca. 3.5-4.0%.

[35] I.e., the terms $e_t^{1+\frac{1}{\psi}}$ and $\ell_t^{1+\frac{1}{\psi}}$ are not multiplied by a free constant.

Externally calibrated parameters		
ψ	3	Frisch elasticity of labor supply
r	4%	Discount rate
s	1.75	Elasticity of substitution
λ	2	Arrival rates of merger opportunities
θ	1.2%	Productivity spillovers

Internally calibrated parameters		
b	0.60	Entry barrier
σ	0.10	Size of the shocks to the firms' productivity
δ	1.40	Productivity of entrepreneurial effort
$E[a]$	-9%	Productivity of new firms
ε_i	2.5%	Exit tolerance
$E[S]$	3.0%	Expected merger synergy
η	0.045%	Productivity parameter of firm's research

Table 3: Calibrated parameters (rates are annualized).

Our internally calibrated parameters were determined as follows. We assumed that the economy adheres to a merger policy of the $N_{\min}$ kind with $N_{\min} = 3$, following Igami and Uetake (2020), who argue that this policy approximates well the US's historic de facto merger policy since 2000. We target the moments in Table 4 below as well as the relative likelihood that entrant firms exit the economy depending on their age: between 0 and 2 years, 2 and 5 years, 5 and 10 years, and 10 to 15 years. Our calibrated model still generates a larger population of old (age 15 and over) firms than present in the US firm data, which we expect, since we target an exit rate of only 3.5-4.0%, taken from Dimopoulos and Sacchetto (2017), who estimate an exit rates in industries with larger, merging firms. We target a lower exit rate than the US average because our model focuses on oligopolistic industries that feature mergers. In the US, firms that merge tend to be publicly traded and exit at the low rates we calibrate.[36]

	Target	*Model*
Annual growth rate of GDP per capita	$1.5 - 1.7\%$	1.61%
Average markup (Lerner index)	$25 - 30\%$	27.5%
Standard deviation of firm TFP	$10 - 15\%$	10.7%
Firm exit rate	$3.5 - 4.0\%$	3.56%
Rate of mergers	$\approx 4.5\%$	4.45%
Mean value gain of mergers	$4 - 17\%$	15.2%
Firm R&D expenditures/revenues	$2 - 5\%$	4.8%

Table 4: Model fit for targeted moments.

[36] Our model's distribution of firms by age under 15 years has a correlation of 0.72 to the data.

We assume that the distribution of merger synergies is uniform: $S \sim U[0, 2E[S]]$, and the expected merger cost synergy $E[S]$ is chosen to match the merger rate and GDP per capita growth rate in Table 4. The expected productivity of a new blueprint, $E[a]$, is set at -9%. We assume that a is uniform, too, with support $[-18\%, 0\%]$. We target a merger rate of 4.5% per year, following Dimopoulos and Sacchetto (2017),[37] and a BGP growth rate of GDP per capita between 1.5% and 1.7%, consistent with long-term growth rates of most developed countries (e.g., the US reported a GDP per capita growth rate from 1991 to 2021 of 1.6%).[38] We target an average markup of 25-30%, consistent with a labor share of 70-75% of net output in major developed economies.[39] David (2021) provides evidence that merger gains may vary from as low as 4% to as high as 17%; we target merger gains in this wide range. We also target the standard deviation of firm total factor productivity between 10% and 15%, which corresponds to a standard deviation in productivity per worker of 30% to 35% across firms.[40]

5 Quantitative Results

This section presents our main results. It compares the economic impact of several merger policies, shows how different aspects of our model contribute to optimal policy, offers various comparative statics, and considers redistributive motives.

5.1 Welfare under Different Merger Rules

Having calibrated our model, we show below the results, in turn, from various merger policies: $N_{\min}$, HHI, ΔHHI, Δp and $\alpha\beta$. Within each policy class, we looked for parameters that maximized welfare, and compared optima across policy classes. We also simulated the 2023 merger guidelines, and report our results below. As we will see momentarily, our results show that an optimal $\alpha\beta$ policy outperformed all other policies, and the 2023 merger guidelines fared significantly worse for households than many other optimal policies.[41]

[37] Alternatively, Cavenaile et al. (2021) targets a slightly lower merger rate of 3.8% per year.

[38] Our economy produces many varieties of goods. Therefore, measured growth rate of output depends on the accounting methodology. We compute the growth rate in line with how the US's national accounts compute GDP growth rates: we measure a chained index of output from quarter t to the next quarter $t+1$ based on the prices of each quarter. That is, first, we compute an output index measured at t's prices in both periods t and $t+1$. Second, we compute the index measured at $t+1$'s prices for outputs of both t and $t+1$. Third, we take the geometric mean of the two indices to compute the growth rate of output from t to $t+1$.

[39] See Piketty and Zucman (2014). Note that the labor share of gross national income is often lower than 70-75% because, in this income concept, capital income includes provisions for capital depreciation and taxes on final goods sales, making gross GDP greater than GDP at factor cost.

[40] This is reported for OECD countries in Berlingieri et al. (2020).

[41] To clarify a technical point, we measured welfare changes from different merger policies in consumption-equivalent terms. First, we defined "status quo welfare" as the representative household's utility under the "status quo" policy of $N_{\min} = 3$, i.e., allowing firms to merge in industries with strictly more than 3 firms (the $N_{\min} = 3$ merger policy). Changes in welfare from other policies are expressed in terms of the changes in consumption needed to attain such status quo welfare.

5.1.1 $N_{\min}$ Rules

We simulated our economy for various choices of $N_{\min}$, with the following main results.[42] Our simulations suggest that the optimal $N_{\min}$ merger rule is 5, but that an even higher $N_{\min}$ rule, such as 6 or 7, yields almost the same welfare; see Figure 7 below. Welfare falls more abruptly if the merger rule is lowered to 4 or 3. Thus, our model suggests that welfare would increase significantly with a stricter $N_{\min}$ policy than the status quo of $N_{\min} = 3$. The model also shows that allowing firms to merge into monopolies (which occurs if $N_{\min} = 1$, since then all mergers are authorized) is a disastrously inefficient policy, halving household utility.

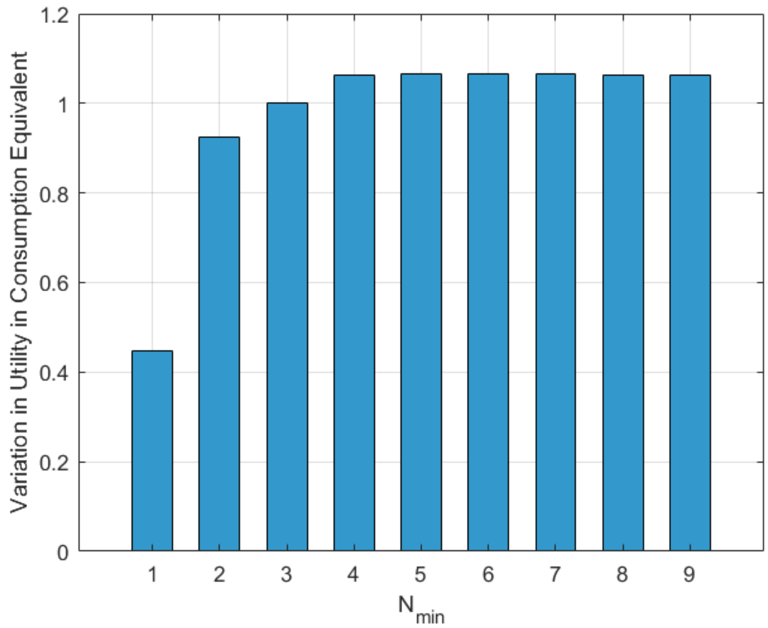

Figure 7: A sample of representative household utility levels from Monte Carlo simulations of the model under different $N_{\min}$ merger rules.

To see why, first note that allowing firms to merge at will results in a significant fraction of industries becoming monopolistic. Table 5 presents the distribution of firms when $N_{\min} = 1$, in the BGP, by industry of size N_{jt} and relative productivity quartile Q in the economy. Table 5 clearly shows not only that many monopolies prevail in the economy in the long run, but also that they are typically relatively less productive than other industries, since they tend to place in the first (i.e., lowest) quartile.

Secondly, note that, in our model, monopolistic firms have very little incentive to innovate. Figure 8 depicts investment in innovation by firms according to the number of firms in their industry. It shows (i) an inverted-U relationship between firm investment in R&D per dollar of firm value with respect to N_{jt}, and (ii) the pattern of absolute firm investment in relation

[42] The $N_{\min} = 1$ policy represents allowing all mergers to proceed even if they lead to industry monopoly, and increasing $N_{\min}$ allows fewer mergers.

Percentage of firms								
Number of firms in industry	1	2	3	4	5	6	7	8
1st quartile	20.12	3.65	4.05	3.97	2.23	0.82	0.17	0.02
2nd quartile	6.42	1.53	3.13	4.32	2.63	0.87	0.16	0.01
3rd quartile	3.92	0.75	3.45	3.78	1.77	0.49	0.08	0.00
4th quartile	5.28	0.79	15.95	8.00	1.51	0.13	0.01	0.00

Table 5: Fraction of firms by industry productivity quartile and number of firms in the industry over time in a Monte Carlo simulation of the economy's BGP when $N_{\min} = 1$. Entries are percentages.

to N_{jt}. Figure 8 clearly shows that monopolies invest less in innovation, both relatively and absolutely. It also shows that absolute innovation investment per firm is maximized in duopoly, according to our calibration. Duopolists invest in innovation not only to stay competitive, but also because duopolistic competition reduces wasteful replication of research and gives firms better returns to their investment, since there are fewer spillovers.

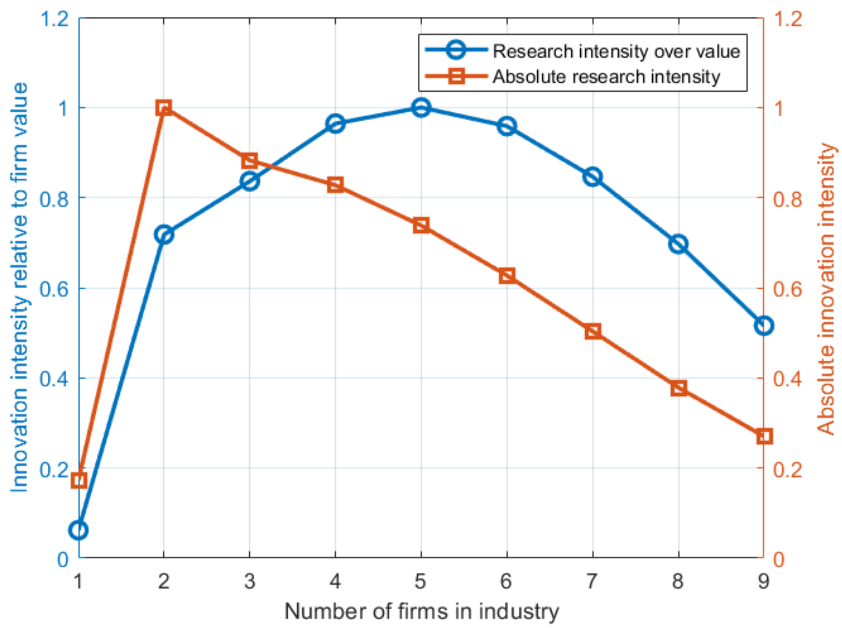

Figure 8: The calibrated model generates an inverted U relationship between competition and innovation incentives. The savings on the reduction of replication of research, however, mean that the absolute rate of innovation is maximized in a duopoly.

Thirdly, firms in oligopolistic industries have their competition-driven innovation incentives dampened by mergers: when more mergers are allowed, oligopolists tend to innovate less because they can grow by merging sooner, at lower cost. This depresses growth in the entire economy. In addition, "growth by merging" reduces significantly the average number of firms per industry in equilibrium, which in turn reduces productivity growth from symbiotic competition, as well as the selection channel for productivity growth.[43] (We discuss the importance of each of these individual effects on growth in Section 5.3 below.) Thus, from $N_{\min} = 3$ to $N_{\min} = 1$, the growth rate of GDP per capita decreases from 1.61% to 1.36%.

Percentage of firms								
Number of firms in industry	1	2	3	4	5	6	7	8
1st quartile	0.00	0.32	9.64	8.41	6.59	2.68	0.61	0.09
2nd quartile	0.00	0.36	9.59	8.72	5.23	1.73	0.33	0.03
3rd quartile	0.00	0.54	9.33	5.82	2.18	0.45	0.06	0.00
4th quartile	0.02	4.97	15.02	5.68	0.89	0.07	0.00	0.00
Merger rate per year								
1st quartile	-	-	-	3.59	1.61	1.17	0.71	1.01
2nd quartile	-	-	-	18.03	12.52	9.58	8.04	7.04
3rd quartile	-	-	-	11.73	5.87	3.42	1.64	1.01
4th quartile	-	-	-	14.10	4.11	1.04	0.22	0.10
Mean	-	-	-	11.73	6.21	4.32	3.19	2.59
Mean growth rate of productivity per year								
1st quartile	-0.25	0.11	1.43	1.91	2.45	2.79	2.98	-
2nd quartile	0.18	1.16	1.70	1.83	2.37	2.74	2.76	-
3rd quartile	0.57	1.10	2.22	3.58	4.02	4.20	-	-
4th quartile	0.22	1.43	2.09	3.13	3.94	5.42	-	-
Mean	0.22	1.19	1.23	2.01	2.25	2.61	2.86	2.92

Table 6: Number of firms, annual merger rate and mean growth rate of industry productivity by industry productivity quartile in a simulation of the economy's BGP at the status quo policy of $N_{\min} = 3$. All entries above are percentages. Dashes mean sample sizes are too small.

Table 6 above depicts the distribution of firms, merger rates, growth rates and number of firms in an industry by productivity quartile when the merger policy is $N_{\min} = 3$. Mergers tend to occur among relatively concentrated industries, and growth rates tend to increase with the number of firms in an industry. These growth rates capture four effects: endogenous innovation, exit of unproductive firms, spillovers, and growth due to the fact that several firms draw random productivity shocks. It does not include the growth effects of mergers, as those displace industries from one column to another on the table. Note that industries with 6 or more firms outperform industries with just 2 or 3, even in the highest quartile.

[43] Entry, exit and stochastic productivity imply that less productive firms tend to exit and be replaced by more productive ones. This selection increases the industry's mean productivity.

5.1.2 HHI and ΔHHI Merger Rules

Our simulations imply that, among HHI rules—where mergers are only allowed if the post-merger HHI score is lower than a threshold—the optimal policy is an HHI score of approximately 2500. On the other hand, under a ΔHHI rule that bounds the change in market concentration instead, the optimal merger policy is approximately ΔHHI = 10: a policy that only allows mergers that do not increase industry concentration by a significant amount.

Figure 9 below depicts some economic consequences of a range of ΔHHI policies. The x-axes depict thresholds for a ΔHHI merger policy, ranging from 0 to 1,600. The various graphs show utility decreasing with the threshold, as more mergers are allowed then, together with labor, the overall growth rate, average number of firms and innovation (roughly). On the other hand, entry and markups increase.

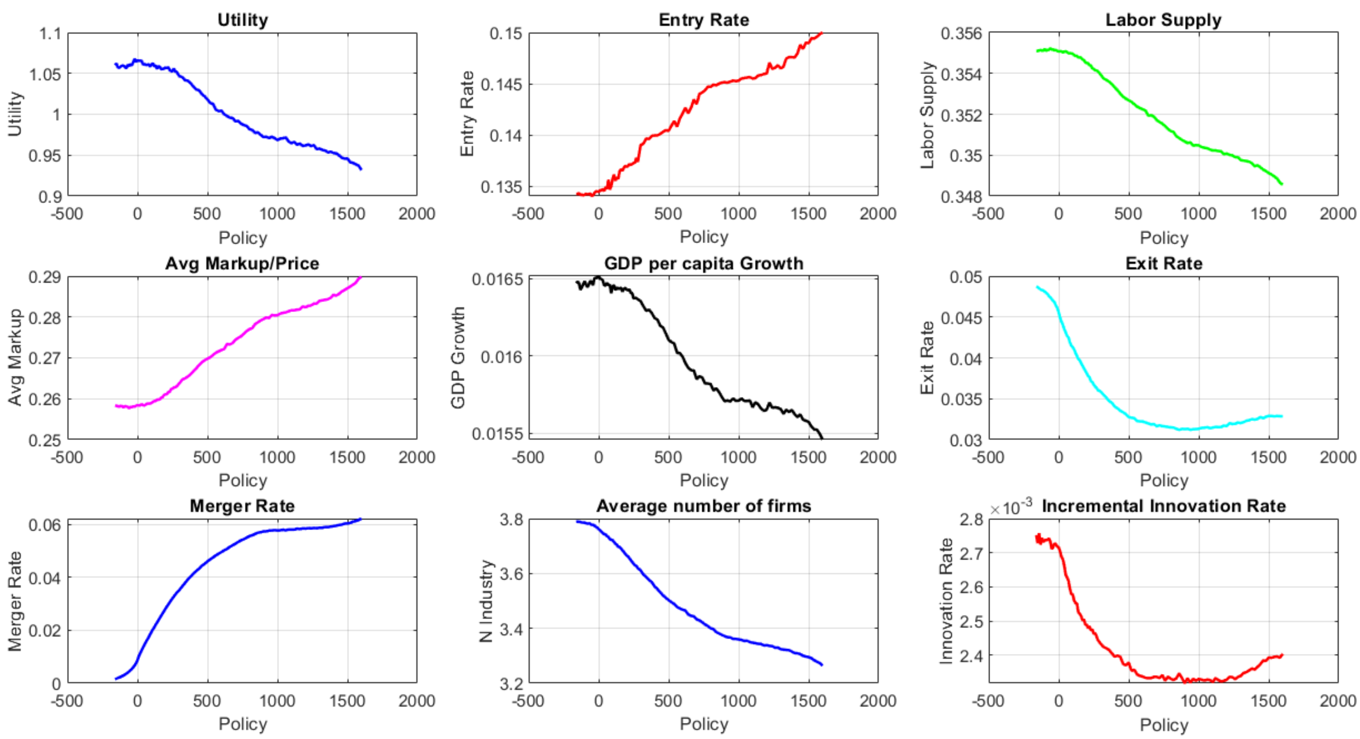

Figure 9: Economic outcomes under different ΔHHI thresholds.

We should point out that many mergers still occur under the very strict policy ΔHHI = 10. Moreover, the representative household's utility is higher under this policy than under the optimal HHI rule. However, as Table 1 shows, both of these rules are dominated by optimal and near-optimal price change policies, considered next.

5.1.3 Price Change Policies

We now present the results of implementing price change policies. We find that these policies outperform previous market concentration-based rules. This is partly because market concentration, cost synergies and static consumer surplus, hence demand elasticity, all enter into the determination of prices pre- and post-merger, so price changes offer a valuable statistic for the analysis of mergers.

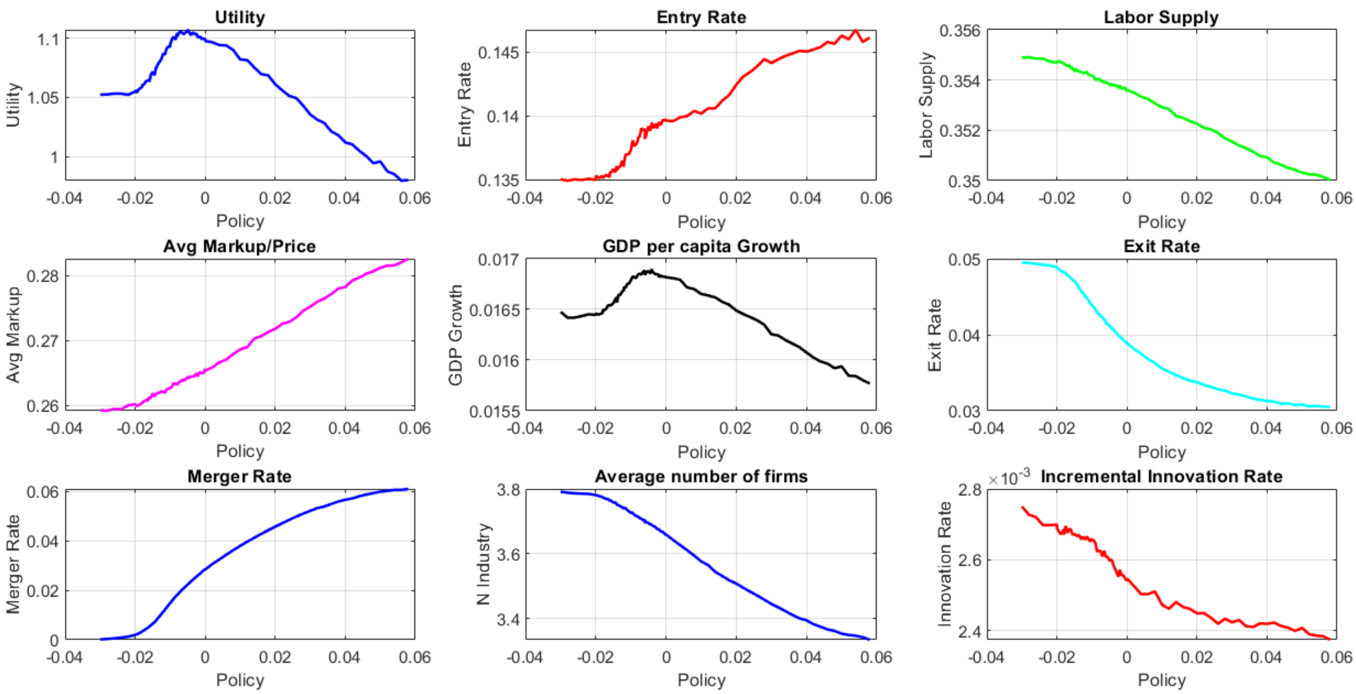

Figure 10: Economic outcomes under different Δp pricing thresholds

Figure 10 above depicts the consequences of a range of price-change merger policies. The x axes track price-change thresholds and the y axes different economic outcomes. Note that the shape of household utility is almost identical to that of economic growth. In other words, welfare is highly correlated with growth. Welfare is maximized at around $\Delta p = -0.5\%$. Thus, merely increasing consumer surplus is not enough to justify a merger under an optimal price change policy. More mergers tend to increase markups and market power, hence entry. However, the net effect is fewer firms per industry and less innovation, symbiotic competition and selection, which lowers overall growth. Quantitatively, starting at a Δp threshold of 2%, hence a merger rate of 4.5% (the status quo), changing policy to decrease the merger rate by 1 percentage point would increase the growth rate of GDP by 2 basis points.

Figure 10 suggests that, as the price threshold increases to permit more mergers, both markups and entry increase. Thus, the higher entry is insufficient to undo the increases of market power. As such, labor and output decrease, as well as innovation, which depresses growth.

5.1.4 $\alpha\beta$ Policies

Now consider $\alpha\beta$ policies: a merger in industry j is blocked if it causes a price change greater than $\alpha+\beta\Delta Z_{jt}$, where ΔZ_{jt} is the difference between industry j's average log-productivity and the economy-wide average, as previously defined. Monte Carlo simulations yield an optimal merger policy of approximately $(\alpha, \beta) = (0, -6\%)$. This means, for instance, that mergers in an industry with productivity 20% below the economy's average should be allowed only if their post-merger price increases by less than 1.2%, whereas mergers in industries whose productivity is 20% above average should go through only if their post-merger price decreases by at least 1.2%.

Percentage of firms								
Number of firms in industry	1	2	3	4	5	6	7	8
1st quartile	0.00	0.35	5.02	10.11	8.01	3.40	0.88	0.14
2nd quartile	0.00	0.37	5.18	9.55	7.01	2.46	0.50	0.06
3rd quartile	0.00	0.50	5.97	8.66	4.22	0.81	0.10	0.00
4th quartile	0.02	4.76	12.94	6.79	1.29	0.12	0.00	0.00
Merger rate per year								
1st quartile	-	-	0.02	0.92	1.66	1.09	0.88	0.69
2nd quartile	-	-	0.73	4.59	7.02	7.68	7.17	5.64
3rd quartile	-	0.00	0.83	4.24	4.50	3.10	1.70	0.61
4th quartile	-	0.14	3.25	4.14	1.45	0.40	0.08	0.07
Mean	-	0.11	1.75	3.36	4.06	3.70	3.07	2.24
Mean growth rate of productivity per year								
1st quartile	-0.27	0.34	1.05	1.69	2.22	2.63	2.99	-
2nd quartile	0.29	0.97	1.53	2.00	2.49	2.94	2.86	-
3rd quartile	0.60	1.09	1.86	2.77	3.39	3.78	-	-
4th quartile	0.16	1.44	2.05	3.25	4.11	4.59	-	-
Mean	0.16	1.20	1.36	1.81	2.17	2.50	2.81	2.95

Table 7: Number of firms, annual merger rate and mean growth rate of industry productivity by industry productivity quartile in a simulation of the economy's BGP at the optimal $\alpha\beta$ policy $(0, -6\%)$. All entries above are percentages. Dashes mean sample sizes are too small.

Table 7 above shows the steady state distribution of firms across industries by number of firms in the industry and industry productivity quartile, as well as merger and growth rates. The firm distribution shows few unproductive monopolies and duopolies. Duopolies tend to become more productive because they invest more in R&D. As such, optimal merger policy renders duopoly mergers rare. The bulk of the economy consists of firms in industries with 3, 4 and 5 firms. Mergers tend to occur in lower-productivity industries with relatively more firms. The nature of Cournot competition means that similar firms tend to have a disincentive to merge without substantial synergies, so merging firms tend to be more asymmetric, rendering mergers closer to acquisitions. Mergers still take place at the top quartile, but only when the number of firms is smaller. In this case, a lower merger synergy is compensated by the prospect of higher profits from market power.

5.1.5 2023 Merger Guidelines

The United States 2023 Merger Guidelines (DOJ and FTC, 2023) updated the DOJ and FTC's legal framework for policing mergers in relation to US antitrust law. We applied these guidelines to our calibrated model and evaluated them in relation to other policies. Our reading of the 2023 Merger Guidelines indicates:

1. A merger application is approved if the post-merger HHI score is below 1800 or if the change in the HHI score is below 100.
2. Otherwise, mergers are allowed after discretionary analysis of individual cases.

In some respects, the merger guidelines provide clear rules for disallowing mergers, but in other respects the guidelines grant considerable discretion to the antitrust authority.[44] To formally capture this varying discretion, we modeled the guidelines as having a probability that a merger is authorized depending on the merger's cost synergies. Thus, a merger that results in lower costs has a higher probability of being authorized. Specifically, if a merger lies squarely in case (1) above it goes through. In case (2), where the post-merger HHI score is above 1800 and the change in the HHI score is above 100, we assumed that if the change in the HHI score is less than 300, the merger is allowed with probability $A(S) = S/(2E[S])$ depending on the merger's cost synergy $S \in [0, 2E[S]]$, so mergers with higher synergies are more likely to be approved. A merger is blocked if the change in HHI exceeds 300.

Our results show (Table 1) that the 2023 Merger Guidelines, as interpreted above, perform poorly relative to other policies. It outperformed the policy of allowing all mergers ($N_{\min} = 1$) as well as the status quo ($N_{\min} = 3$) and the policy of allowing no mergers whatsoever, but was significantly outperformed by the best $N_{\min}$, ΔHHI, Δp, and $\alpha\beta$ policies. It was even outperformed by the "static" policy of $\Delta p = 0$. Thus, a simple price policy might be more effective than the current guidelines.

[44] The guidelines also touch on many other important issues of competition policy that we set aside in this paper, such as collusion and market definition. Our focus here is on merger policy.

5.2 Decomposition of Policy Determinants

In this subsection we decompose static and dynamic effects of merger policy. Then, to better understand our results, we consider the case where innovation is exogenous at the status quo level, followed by the case where entry is exogenous, again at the status quo.

5.2.1 Static versus Dynamic Effects of Merger Policy

Throughout the paper, we have claimed that, in our endogenous growth framework, the dynamic effects of merger policy are much more important for welfare and for modulating policy parameters than the static effects. We make this argument explicitly next.

Table 8 below records (consumption-equivalent) welfare in three scenarios: (i) our best merger policy (an $\alpha\beta$ policy with $(\alpha, \beta) = (0, 6\%)$), (ii) the policy of allowing all mergers (called "monopoly"), and (iii) allowing all mergers but assuming away static factor misallocation caused by market power relative to the best $\alpha\beta$ policy in (i), which we called monopoly*.[45]

	Welfare	*Change in log welfare*
Best $\alpha\beta$ policy	1.113	0.872
Monopoly*	0.522	0.114
Monopoly	0.466	0.000

Table 8: Changes in welfare relative to the optimal policy. We consider (i) allowing all mergers up to monopoly, and (ii) the monopoly* case where all mergers are allowed but the same degree of allocative efficiency as in the best $\alpha\beta$ policy is assumed.

Approximately 87% of the decrease in (log-consumption-equivalent) welfare from our best policy to monopoly is caused *not* by static factor misallocation, but by the welfare losses from *dynamic* channels that lead to slower productivity growth. The static welfare effect of monopoly only accounts for 13% of the change in welfare. Intuitively, allowing all mergers means fewer firms innovating and learning from each other, which reduces productivity growth, and that reduction in productivity growth accounts for the vast majority of the fall in welfare from allowing all mergers, while the rise of market power is relatively less important.

Thus, although markups do matter for welfare and competition policy, according to our model they do not matter as much as economic growth. The effect of markups can be further decomposed into two parts: (i) allocative inefficiency due to labor supply elasticity and wages being lower than the marginal product of labor, and (ii) allocative inefficiency due

[45] Specifically, we corrected static distortions from markups on labor and markup asymmetry across industries. For the monopoly* case, we reduced these two distortions to the levels of case (i) and kept all other firm behavior as in the monopoly case. We did so by increasing household utility to match the implied increase in labor supply (increased output and disutility of labor) and reallocated labor across industries (also increasing output) to match the distortions of case (i).

to misalignment of markups across industries. Factor misallocation across industries accounts for only 2% of the effect of changing competition policy on welfare, while the distortion on the labor supply due to markups accounts for 11%, and the dynamic factors account for 87%.

5.2.2 Decomposition of Dynamic Channels

Next, let us decompose the dynamic effects of competition policy on welfare. We consider three main dynamic channels affecting merger policy by progressively shutting them down: first, we consider a situation where firm-level innovation is exogenously fixed, then we suppose there is neither symbiotic competition nor the selection process driven by productivity shocks. Finally, we shut down the choice of entrepreneurial effort by households. Given our calibration, this exercise suggests that the first case is far more important for optimal merger policy.

Case 1: Exogenous Innovation by Firms. We removed the choice of innovation effort by incumbent firms and exogenously fixed productivity growth parameters μ_{it} for each firm at 0.3%. Keeping all other parameters of the model the same, this change in the model implies a more permissive merger policy. Specifically, the optimal price change policy increases from -0.5% to approximately -0.1%, and the merger rate increases from 2.2% to 2.6%. Intuitively, when firms can choose their innovation, more mergers reduce firms' incentives to innovate.

Case 2: Symbiotic and Selection Effects. In addition, we considered removing symbiotic competition and the stochasticity of firms' productivity: we set $\theta = \sigma = 0$, so there are no shocks to firm productivity except for entrants'. The opportunity costs of losing symbiotic competition and firm selection now both cease to exist, since they rely on randomness. Keeping all other parameters fixed with innovation still exogenous as above, the optimal price change policy changes radically: it increases from -0.1% (Case 1) to 2.8%, and the merger rate reaches 6.8%, three times higher than in our baseline environment and our optimal price change policy. Therefore, endogenous innovation, symbiotic competition and selection have a significant effect on competition policy in our calibration.

Case 3: Exogenous entry. Finally, we took away households' choice of entrepreneurial effort. We restored endogenous innovation, spillovers and selection, and fixed effort at a level consistent with a GDP per capita growth rate of 1.7% under the optimal merger policy, leaving the model unchanged otherwise. The benefit of increasing markups to induce greater innovation was reduced, but the magnitude of this effect on optimal policy was small: the optimal price change policy decreased slightly from -0.5% to -0.6%, and the merger rate stayed at approximately the same level of 2.2%. While entry of new firms can contribute to growth in our model (as in Klette and Kortum, 2004), our calibration of entrants' expected productivity means that productivity gains from new firm entry are paltry compared to other channels of TFP growth: this channel plays a relatively minor role in affecting merger policy.

5.3 Main Trade-offs in Merger Policy

In our dynamic general equilibrium model, the main mechanisms driving the welfare effects of merger policies are their effects on the growth rate of output/consumption, while allocative issues have second-order effects (as was discussed in Section 5.2). The growth rate of consumption is mainly driven by the following five channels: (i) symbiotic competition, i.e., firms growing through competition-driven investment and knowledge spillovers, (ii) selection from random shocks, where low-productivity firms exit and firms that receive positive shocks increase their market share, which, together with entry of new firms, generates "Darwinian" productivity increases, (iii) innovation investments made by firms, (iv) cost synergies from mergers, that is, when merger rules are relaxed and merger rates increase, more cost synergies are exploited, and (v) duplication of research, i.e., when the merger rate increases due to a more permissive policy, there is a decrease in the average number of firms per industry, and as such their investment in R&D becomes more efficient it reduces research duplication.

Consider price change policies. Moving from $\Delta p = -3\%$, where nearly all mergers are forbidden, to a policy of $\Delta p = -0.5\%$ implies an increase in the merger rate from 0.01% to 2.24%. This significant increase in mergers decreases the average number of firms across industries (reducing growth from symbiotic competition and selection) and decreases firms' mean investment in innovation. However, the gains from channels (iv)-(v) are greater, thus economic growth increases significantly from 1.65% to 1.69%. As Δp is further relaxed from -0.5% to 3%, the loss in growth from channels (i), (ii) and (iii) dominates the gains from channels (iv) and (v), and the growth rate of output decreases from 1.69% to 1.63%.

Mergers reduce innovation incentives, productivity growth and the average number of competing firms. Still, despite our assumption that firms find merger opportunities often (at a rate of 50% per quarter), our simulations suggest that optimal merger policy is not extremely strict. In our model, firms choose to *not* take up the vast majority of merger opportunities. This is partly due to productivity spillovers, which erode a merger's long-run value. To see this, consider an industry with a fixed number of $N > 2$ firms. Knowledge spillovers lead firms' productivity towards mutual convergence in the long run, or at least curtail divergence,[46] roughly pushing firms towards equal market shares of $1/N$. For a pair of firms that merge, the merged entity's market share will tend to $1/(N-1)$, which is strictly smaller than the long-run expected combined market shares of two out of N firms, $2/N$. This clearly reduces post-merger Cournot profits.[47] Thus, for firms to benefit from a merger, cost synergies must be substantial enough to overcome this market-share reduction effect.

[46] See, e.g., Guthmann and Rahman (2025) for an elaboration of this argument.

[47] The point that pairs of symmetric firms do not wish to merge in Cournot oligopoly with $N \geq 3$ firms and symmetric technologies was made by Salant et al. (1983). Perry and Porter (1985) pointed out that mergers need some productivity synergies to occur.

5.4 Robustness to Redistributive Motives

Antitrust policy and public policy in general are often concerned with distributional aspects. Typically, policies tend to focus on maximizing the welfare of lower-income groups (maximizing what one might call a "Rawlsian welfare function") or accounting only for worker surplus, as considered by Berger et al. (2023).

As lower income groups typically tend to earn most of their income from labor, we consider an extension of the model where there are two representative households: a working household that only supplies labor and an entrepreneurial household that only supplies entrepreneurial effort. The working household's utility flow is given by

$$U_w(c_{wt}, \ell_t | Y_t) = \left(\int_0^1 c_{wjt}^{\frac{s-1}{s}} \mathrm{d}j \right)^{\frac{s}{s-1}} - \ (\ell_t)^{1+\frac{1}{\psi}} \times Y_t, \tag{6}$$

where c_{wjt} stands for consumption by the working household of variety j at time t. The entrepreneurial household utility flow is given by

$$U_e(c_{et}, e_t | Y_t) = \left(\int_0^1 c_{ejt}^{\frac{s-1}{s}} \mathrm{d}j \right)^{\frac{s}{s-1}} - \ (e_t)^{1+\frac{1}{\psi}} \times Y_t, \tag{7}$$

where c_{ejt} stands for consumption by the entrepreneurial household of variety j at time t.

For simplicity, we continue to assume that there are no credit markets, so households cannot consume more than their income at every point in time.[48] Therefore, the level of consumption of the composite good by the worker's household equals output times the labor share of income:

$$c_{wt} = Y_t \times LS_t,$$

where LS_t is the labor share at time t. Correspondingly, the level of consumption by the entrepreneurial household equals output times one minus the labor share of income:

$$c_{et} = Y_t \times (1 - LS_t).$$

Figure 11 below depicts overall welfare in the economy (green) together with welfare of working households only (blue) as a function of different Δp policy thresholds. Suppose that the competition authority aims to maximize only the utility of the worker household. In this case, as Figure 11 shows, the optimal price-change policy is slightly more strict than for the representative household: the optimal policy decreases from -0.50% to -0.75%. However, welfare levels do not change significantly between -0.50% and -0.75%. The merger rate decreases significantly under respectively optimal policies across the two welfare criteria, from 2.24% to 1.89%, since the optimal pricing policy change across welfare criteria is not insignificant.

[48] As income shares are constant in the BGP and both households have the same time preferences, there is no incentive for intertemporal trade.

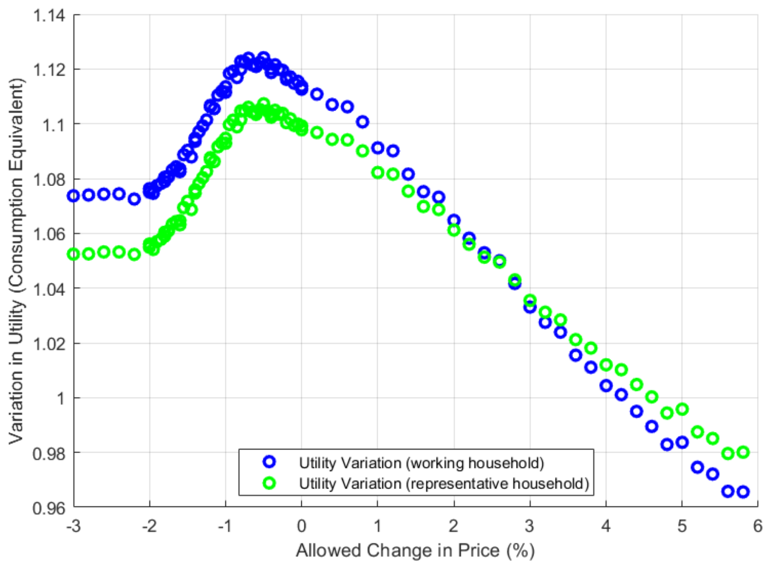

Figure 11: Effects of merger policy on the utility of working households in contrast with the representative household under different Δp policies.

6 Conclusion

This paper develops a rich and computationally tractable model of horizontal merger policy embedded in dynamic general equilibrium. In our model, horizontal mergers impact welfare along several dimensions: (i) they increase deadweight losses from market power, (ii) synergies decrease costs post-merger, (iii) thanks to higher expected profits, mergers motivate entry, (iv) they affect investment in R&D, productivity spillovers across firms, and firm selection effects, and (v) mergers decrease deadweight losses from research replication.

We studied half a dozen different classes of merger policies, and computed optimal policies within each policy class. According to our calibration, the second and fourth dimensions in which mergers affect welfare appear to be the most important. By experimenting with different merger policy classes, we concluded that conditioning mergers on maximal post-merger price changes in the industry outperformed other kinds of merger policy, including the current 2023 merger guidelines. Stiffening price-change policies in line with endogenous entry barriers (our $\alpha\beta$ policies) maximized welfare overall. There, as industries become more productive and entry barriers increase, welfare is maximized by protecting consumers from their mergers, consistent with Brandeis's view of the regulation of competition. We analyzed mergers through a "Schumpeterian" lens and found that welfare effects of mergers through dynamic channels are much larger than static effects on allocative efficiency: economic growth was an order of magnitude more important than static welfare losses. This implies that what matters most for merger policy is effects on output dynamics and growth, not short-run effects on factor allocation across industries, such as markups and their alignment.

Our quantitative analysis suggests that a "static" merger policy (i.e., an industry's post-merge price cannot increase) appears to be a good approximation of optimal policy in our dynamic economy. Thus, the static rationale seems to provide a valuable heuristic for close-to-optimal merger policy. Finally, our results suggest that, even though static welfare losses from market power per se are not the key drivers of welfare for optimal merger policy, the expression of market power through markups is symptomatic of inherent problems to do with incentives to innovate and thereby grow the economy. More market power breeds stagnation. In conclusion, the rise of market power can have pernicious dynamic effects on the economy.

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Appendix

A Proofs

Proof of Lemma 1

Since the household's utility is additively separable over time, we may treat consumption at each time t individually. The budget problem at t is then

$$\max_{c_t \geq 0} \left(\int_0^1 c_{jt}^{\frac{s-1}{s}} dj \right)^{\frac{s}{s-1}} \quad \text{s.t.} \quad \int_0^1 p_{jt} c_{jt} dj \leq y_t.$$

Kuhn-Tucker conditions yield

$$\left(\frac{\|c_t\|}{c_{jt}} \right)^{\frac{1}{s}} \leq \lambda p_{jt},$$

where λ is the multiplier on the time-t budget constraint. Since $s > 1$, this condition holds with equality. Thus, rearranging,

$$c_{jt} = \frac{\|c_t\|}{(\lambda p_{jt})^s}$$

for each good variety $j \in [0,1]$. Now, given $j, k \in [0,1]$, it follows that

$$c_{kt} = c_{jt} \left(\frac{p_{kt}}{p_{jt}} \right)^{-s}.$$

Therefore,

$$y_t = \int_0^1 p_{kt} c_{kt} dk = \int_0^1 p_{kt} c_{jt} \left(\frac{p_{kt}}{p_{jt}} \right)^{-s} dk = c_{jt} p_{jt}^s \int_0^1 p_{kt}^{1-s} dk.$$

This implies that

$$c_{jt} = \frac{y_t p_{jt}^{-s}}{\int_0^1 p_{kt}^{1-s} dk}.$$

Moreover,

$$c_{jt}^{\frac{s-1}{s}} = \frac{y_t^{\frac{s-1}{s}} p_{jt}^{1-s}}{\left(\int_0^1 p_{kt}^{1-s} dk \right)^{\frac{s-1}{s}}},$$

therefore

$$\int_0^1 c_j^{\frac{s-1}{s}} dj = \frac{y_t^{\frac{s-1}{s}}}{\left(\int_0^1 p_{kt}^{1-s} dk \right)^{-\frac{1}{s}}}$$

and

$$\|c_t\| = \frac{y_t}{\left(\int_0^1 p_{kt}^{1-s} dk \right)^{\frac{1}{1-s}}}.$$

Substituting the normalization $\int_0^1 p_{kt}^{1-s} dk = 1$ above completes the proof. □

Proof of Lemma 2

Recall the profit formula for a firm $i \in I_{jt}$:

$$R_{it}(q_{jt}) = \left[\left(\frac{y_t}{Q_{jt}} \right)^{\frac{1}{s}} - \gamma_{it} \right] q_{it}.$$

The first-order necessary condition for an optimum is given by

$$\left(\frac{y_t}{Q_{jt}} \right)^{\frac{1}{s}} - \gamma_{it} - \frac{1}{s} \left(\frac{y_t}{Q_{jt}} \right)^{\frac{1}{s}} \frac{q_{it}}{Q_{jt}} = 0$$

for each $i \in I_{jt}$ with $q_{it}^* > 0$, therefore

$$\frac{q_{it}}{Q_{jt}} = s \left[1 - \gamma_{it} \left(\frac{y_t}{Q_{jt}} \right)^{-\frac{1}{s}} \right].$$

Adding these first-order conditions with respect to $i \in I_{jt}^*$ gives

$$\Gamma_{jt}^* \left(\frac{y_t}{Q_{jt}} \right)^{-\frac{1}{s}} = |I_{jt}^*| - \tfrac{1}{s}.$$

Substituting for $(|I_{jt}^*| - \frac{1}{s})/\Gamma_{jt}^*$ from this expression into the first-order condition above it finally yields the claimed market-share equation. □

Proof of Proposition 1

Without loss of generality, assume $\mu_{it} = 0$ and consider an industry with N firms. Denote maximum productivity in the industry by $Z_t^* = \max\{Z_{kt} : k \in \{1, \ldots, N\}\}$ and recall (3):

$$\mathrm{d}Z_{it} = \begin{cases} \theta \mathrm{d}t + \sigma \mathrm{d}W_{it} & \text{if } Z_{it} < Z_t^* \text{ and} \\ \sigma \mathrm{d}W_{it} & \text{if } Z_{it} = Z_t^*, \end{cases}$$

By Proposition 5.3.6 of Karatzas and Shreve (1988, p. 303), this has a weak solution

$$Z_{it} = Z_{i0} + \int_0^t b_i(Z_{1s}, \ldots, Z_{Ns}) ds + \widehat{W}_{it},$$

where $b_i(Z_{1s}, \ldots, Z_{Ns})$ is the drift of Z_{it} implied by (3) and $\widehat{W}_{it}$ is a Wiener process. Since the set $\{s \geq 0 : Z_{ks} = Z_{k's} \text{ for some } k, k' \in \{1, \ldots, N\}\}$ of times where there is a productivity tie for some firms has Lebesgue measure zero almost surely (Karatzas and Shreve, 1988, Theorem 2.9.6), letting $Z_{-it}^* = \max\{Z_{kt} : k \in \{1, \ldots, N\} \setminus \{i\}\}$, the vector process $(Z_1, \ldots, Z_N)$ also weakly solves

$$\mathrm{d}Z_{it} = \begin{cases} \theta \mathrm{d}t + \sigma \mathrm{d}\widehat{W}_{it} & \text{if } Z_{it} < Z_t^*, \\ \sigma \mathrm{d}\widehat{W}_{it} & \text{if } Z_{it} > Z_{-it}^*, \text{ and} \\ \frac{N_t^*-1}{N_t^*}\theta \mathrm{d}t + \sigma \mathrm{d}\widehat{W}_{it} & \text{if } Z_{it} = Z_{-it}^*, \end{cases} \tag{3'}$$

where $N_t^* = |\arg\max\{Z_{kt} : k \in \{1, \dots, N\}\}|$ is the number of firms with highest productivity. Hence, by (3), average productivity $\bar{Z}_t = (Z_{1t} + \cdots + Z_{Nt})/N$ has the requisite law of motion

$$\begin{aligned} \mathrm{d}\bar{Z}_t &= \tfrac{N_t^*}{N}\tfrac{N_t^*-1}{N_t^*}\theta \mathrm{d}t + \tfrac{N-N_t^*}{N}\theta \mathrm{d}t + \sigma \tfrac{1}{N}\textstyle\sum_k \mathrm{d}\widehat{W}_{kt} \\ &= \tfrac{N-1}{N}\theta \mathrm{d}t + \tfrac{1}{\sqrt{N}}\sigma \mathrm{d}W_t, \end{aligned}$$

where $W_t = (\widehat{W}_{1t} + \cdots + \widehat{W}_{Nt})/\sqrt{N}$ is a Wiener process, since $\mathrm{E}[\mathrm{d}W_t] = 0$ and

$$\mathrm{Var}(\mathrm{d}W_t) = \textstyle\sum_k \mathrm{Var}(\mathrm{d}\widehat{W}_{kt})/N = \mathrm{d}t. \quad \square$$

Proof of Proposition 2

To see that the balanced growth path exists and is unique, first note that the representative household's demands are well-defined given income and prices for each variety and that for a set of firms competing in an industry with constant marginal costs facing a constant elasticity demand, a Markov perfect equilibrium under Cournot competition always exists. Second, note that the representative household's labor supply is determined by the labor share of output, which is determined by the average markup.

Therefore, to prove the existence of a BGP, it only remains to show that there exists a level of entrepreneurial effort e^* that is consistent with a BGP. To show uniqueness, such an e^* needs to be unique. To show that $e^* > 0$, we need to show that $e^* = 0$ is not consistent with a BGP.

Consider some fixed level of entrepreneurial effort e^* for an indeterminate period of time. This implies a fixed supply of new blueprints which, taking the time horizon to infinity, implies a constant growth rate of the final output. Specifically:

1. A constant rate of production of blueprints implies a constant rate of entry of new firms.

2. Assuming that such constant effort level e^* lasts for $t \to \infty$ then the distribution of firms by age and number across industries converges to a stationary distribution across the unit interval of industries in operation.

3. Consequently, the symbiotic effect and the growth in productivity from blueprints are both constant in the aggregate economy. Therefore, we have a constant rate of aggregate growth in productivity.

The uniqueness of the equilibrium under a balanced growth path (BGP) arises because the profitability of new blueprints is strictly decreasing with increased effort. As more blueprints are produced, competition intensifies, leading to lower margins. Therefore, there exists a unique equilibrium effort level e^* consistent with a balanced growth path.

Furthermore, the effort level is always greater than zero because: 1. The expected profitability of starting new firms remains positive. 2. The marginal disutility of effort is zero at zero effort. Therefore, 1-2 ensures that some positive level of effort is always optimal. Thus, we have shown that there exists a unique equilibrium effort level $e^* > 0$ consistent with the balanced growth path. □

Proof of Proposition 3

We begin by considering a discrete-time approximation of the model, where each period t has duration $dt \to 0$. Suppose that time is discrete: $t \in \{0, dt, 2dt, \ldots\}$. At the start of a period t, every industry j starts in state (I_{jt}, Z_{jt}), and any firm whose marginal cost exceeds the exit threshold exits, leaving the firm set $\hat{I}_{jt}$ with log-productivity profile $\hat{Z}_{jt}$, as defined in Section 3. Relying on the notation developed there, the discrete-time Bellman equation for a firm that does not exit at time t is

$$\begin{aligned}
\hat{V}_{it} = &\max_{(q_{it},\mu_{it})\geq 0} \; \hat{\Pi}_{it}dt + (1-rdt)\times \\
&\Bigg([1-(\delta e_t + \tfrac{1}{2}\lambda \hat{N}_{jt}(\hat{N}_{jt}-1))dt]E[V_{it+dt}|\hat{Z}_{jt}] + \delta e_t dt E[V_{it+dt}^{\{i'_{t+dt}\}}|\hat{Z}_{jt+dt}] + \\
&\lambda dt \sum_{k\in \hat{I}_{jt}\setminus\{i\}} V_{it+dt} + \tfrac{1}{2}E[(V_{\{i,k\}t+dt}^{\{i,k\}} - (V_{it+dt}+V_{kt+dt}))\mathbf{1}_{jt}^{\{i,k\}}|\hat{Z}_{jt+dt}] + \\
&\tfrac{1}{2}\lambda dt \sum_{k,k'\in \hat{I}_{jt}\setminus\{i\}} E[V_{it+dt}^{\{k,k'\}}\mathbf{1}_{jt}^{\{k,k'\}} + V_{it+dt}(1-\mathbf{1}_{jt}^{\{k,k'\}})|\hat{Z}_{jt+dt}]\Bigg).
\end{aligned}$$

Subtracting $(1-rdt)\hat{V}_{it}$ from both sides and dividing by dt gives

$$\begin{aligned}
r\hat{V}_{it} = &\max_{(q_{it},\mu_{it})\geq 0} \; \hat{\Pi}_{it} + (1-rdt)\times \\
&\Bigg([1-(\delta e_t + \tfrac{1}{2}\lambda \hat{N}_{jt}(\hat{N}_{jt}-1))dt]\frac{E[V_{it+dt}|\hat{Z}_{jt}] - \hat{V}_{it}}{dt} + \delta e_t\big(E[V_{it+dt}^{\{i'_{t+dt}\}}|\hat{Z}_{jt}] - \hat{V}_{it}\big) + \\
&\lambda \sum_{k\in \hat{I}_{jt}\setminus\{i\}} \big(V_{it+dt} + \tfrac{1}{2}E[(V_{\{i,k\}t+dt}^{\{i,k\}} - (\hat{V}_{it+dt}+\hat{V}_{kt+dt}))\mathbf{1}_{jt}^{\{i,k\}}|\hat{Z}_{jt}] - \hat{V}_{it}\big) + \\
&\tfrac{1}{2}\lambda \sum_{k,k'\in \hat{I}_{jt}\setminus\{i\}} \big(E[V_{it+dt}^{\{k,k'\}}\mathbf{1}_{jt}^{\{k,k'\}} + V_{it+dt}(1-\mathbf{1}_{jt}^{\{k,k'\}})|\hat{Z}_{jt}] - \hat{V}_{it}\big)\Bigg).
\end{aligned}$$

As $dt \to 0$, clearly $1 - rdt \to 1$. Since all firms in $\hat{I}_{jt}$ are in the interior of their non-exit region, Ito's Lemma implies that

$$[1 - (\delta e_t + \tfrac{1}{2}\lambda \hat{N}_{jt}(\hat{N}_{jt} - 1))dt] \frac{E[V_{it+dt}|\hat{Z}_{jt}] - \hat{V}_{it}]}{dt} \to \sum_{k \in \hat{I}_{jt}} (\mu_{kt} + \theta \mathbf{1}^k_{jt}) \frac{\partial \hat{V}_{it}}{\partial Z_k} + \tfrac{1}{2}\sigma^2 \frac{\partial^2 \hat{V}_{it}}{\partial Z_k^2}.$$

Finally, the remaining terms converge to their corresponding ones in the statement of Proposition 3 by continuity of the value function. □

B Robustness Tests

B.1 Individual Effects of Main Channels

Mergers affect the representative household's welfare through several channels. First, changes in concentration have effects that depend on the degree of market power of industries. Second, the effects of mergers on welfare also have several dynamic channels: mergers change the economy's growth rate by changing the profitability of starting new firms, realizing the merger's potential productivity increase from synergies between the merged firms, the change in the distribution of the number of firms across industries from increase in mergers changes the effects of symbiotic competition and selection effects on productivity growth, and they also change the incentives for firms to invest in innovation.

Our model suggests that these dynamic channels are very important for determining optimal merger policy. This is evident if we consider that, under our calibration, the correlation between the representative household's utility and the growth rate of GDP per capita is 0.997 with respect to variations in Δp policy. We also consider Case 7, where we shut all dynamic channels (symbiotic competition, innovation, and endogenous firm entry) and show that it yields a substantial difference in terms of optimal policy.

These robustness tests also show that our optimal policy is quite robust to changes in individual parameters, keeping all other parameters fixed, except for merger cost synergies: high-cost synergies justify a substantially more permissive merger policy.

Case 1: Market Power—Elasticity of Substitution. Increasing the elasticity of substitution across varieties from 1.75 to 2.75, which raises competition among firms across industries, reduces markups and, therefore, the profitability of firms. This leads to a lower entry rate of startups, which leads to a lower degree of competition within industries, with the average number of firms per industry decreasing by a quarter. Therefore, despite this change of parameters making competition across industries more intense, the optimal Δp merger policy becomes more strict—decreasing from -0.5% to approximately -0.8%. On the other hand, the merger rate at each optimal policy increases from 2.24% to 2.8%.

Case 2: Market power—Elasticity of labor supply. Changing the Frisch elasticity of labor and effort supply ψ from 3 to 1 decreases the optimal Δp policy from -0.50% to approximately -0.30%. The merger rate at the optimal policy substantially increases from 2.24% to 3.3%. The change in elasticity allows for the optimal Δp policy to approve some more mergers as the degree of distortion of labor time allocation due to markups is decreased.

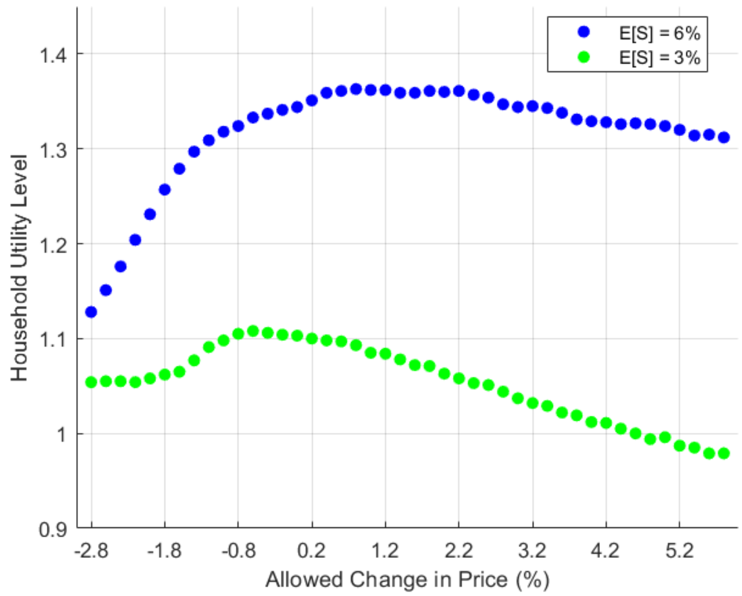

Figure 12: A sample of representative household utility levels from Monte Carlo simulations of the model under different merger policies at two levels of expected cost synergies from mergers.

Case 3: Cost Synergies. Increasing the expected cost synergy of mergers from 3.0% to 6.0% (shifting the uniform distribution of cost synergy to $[0, 0.12]$), the optimal Δp policy increases from -0.5% to approximately 0.9% as shown in Figure 12. The equilibrium merger rate at the optimal policy greatly increases from 2.24% to 6.9%.

Merger cost synergies represent a productivity increase from a merger: the macroeconomic consequence of this feature is that this channel has the effect that an increase in merger rate tends to increase the productivity growth rate. One reason is that a merger cost synergy increases the productivity of other firms over time thanks to spillovers. As the elasticity of the productivity growth rate to mergers increases thanks to increased synergies, an optimal policy allows mergers to increase prices in the short run.

Case 4: Incremental innovation. If we increase the productivity of firms' innovation η from 0.045% to 0.090%, the optimal Δp policy becomes slightly more restrictive, changing from -0.5% to approximately -0.7%. The merger rate at the optimal policy decreases slightly from 2.24% to 2.0%. As blocking more mergers increases firms' average innovation level, if this channel becomes more important, it increases the opportunity cost of mergers.

Case 5: Reduction of Symbiotic Competition. If we decrease the intensity of symbiotic competition by increasing the productivity spillover parameter θ from 1.2% to 0.6%, the optimal Δp policy increases from -0.5% to -0.2%. The merger rate at the optimal policy nearly doubles from 2.24% to 4.1%. As the productivity gains from symbiotic competition are lower, mergers have a smaller cost in terms of reduction of competition; thus, the optimal policy should allow for more mergers. Note that the relative importance of incentives to innovate increases: lower productivity spillovers imply that the elasticity of the GDP growth rate to the merger policy increases, as shown in Figure 14. Apparently, our calibrated parameters suggest that both effects cancel out in their effects on the optimal policy.

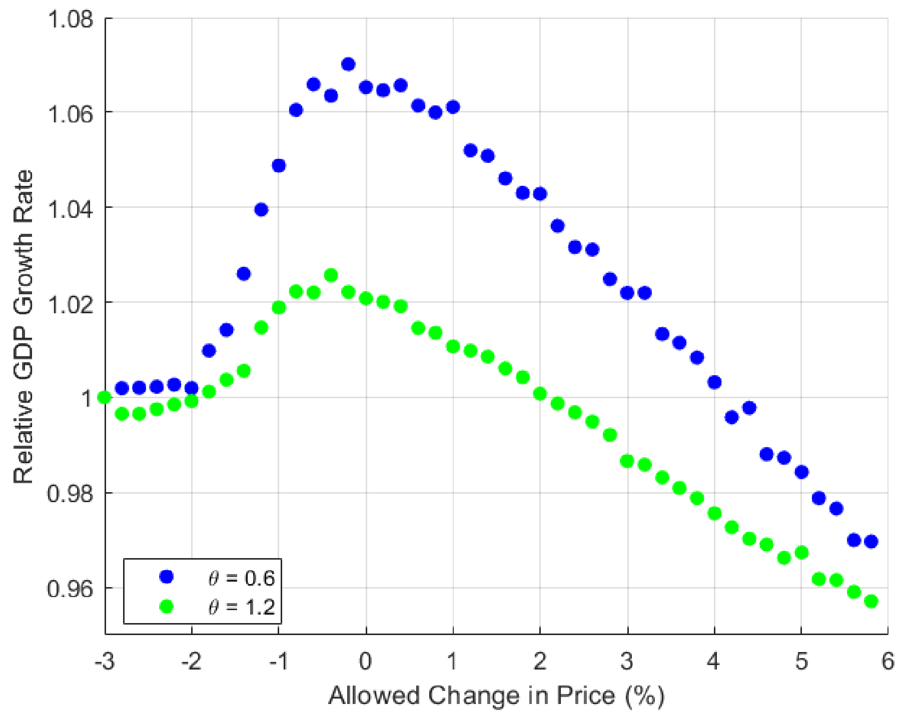

Figure 13: A sample of relative GDP growth rates from Monte Carlo simulations of the model under different levels of productivity spillovers and merger policies.

Case 6: Firm creation. Finally, if we double the productivity parameter of a household's entrepreneurial effort δ from 1.4 to 2.8, the optimal Δp policy increases from approximately -0.5% to -0.2%. The merger rate at the optimal policy substantially increases from 2.24% to 3.6%. The reason is that a higher expected markup incentivizes the creation of new firms. Therefore, if the creation of firms is more elastic with respect to entrepreneurial effort, optimal policy should allow more mergers.

B.2 Merger Bargaining Weights

We previously assumed in the main version of the model that merging firms have equal bargaining power in sharing the surplus value from a merger, irrespective of the relative sizes/market shares of the merging firms. It makes intuitive sense to consider a robustness test of the model that allows for larger firms to have greater bargaining power in sharing the surplus from a merger. Increasing the bargaining power of the larger firm, implying its share of the surplus changes from 0.50 to 0.75 has a very small effect on merger policy: the optimal Δp policy, changes from ca. -0.50% to ca. -0.40%.

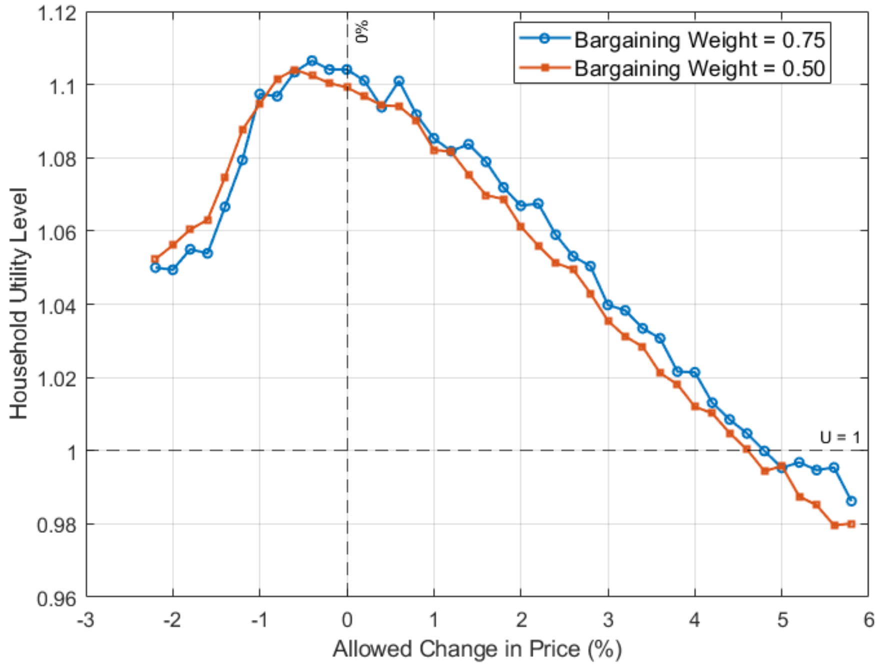

Figure 14: A sample of relative (consumption equivalent) utility levels from Monte Carlo simulations of the model under different merger bargaining power and merger policies.

B.3 Value Function Estimation

In this subsection, we modify the method we used to approximate the value of firms to test whether our quantitative results are robust: we attempt to increase the precision of our approximation method by dividing the set of firms into finer partitions and by estimating a higher-degree polynomial regression on the firms' value.

Different Regression Estimating the Value Function

For an industry in productivity quartile Q and with N_{jt} firms, consider an alternative estimate of the firms' value V_{it} using the following polynomial fit with the firm value data generated by the Monte Carlo simulations:

$$V_{it}^e = \alpha_{Q,N_{jt}} + \beta^1_{Q,N_{jt}}(Z_{it} - EZ_{jt}) + \beta^2_{Q,N_{jt}}(Z_{it} - EZ_{jt})^2 + \beta^3_{Q,N_{jt}}(Z_{it} - EZ_{jt})^3 + \beta^4_{Q,N_{jt}} Var(Z_{ktk \neq i}),$$

where now there is an additional regression parameter $\beta^3_{Q,N_{jt}}$ relative to the specification in (5). The optimal Δp policy does not change and is still approximately -0.5%.

Increasing the Number of Productivity Quantiles

Instead of partitioning the set of industries into four productivity quartiles, consider partitioning into 6 approximate quantiles of industries with mean productivity 12% below the mean, 12-6%, and 6-0% below the mean, and 0 to 6%, 6-12%, above 12% above the mean. For each productivity quantile $Q \in \{1, 2, 3, 4, 5, 6\}$ we partition the firms into industries of $N_{jt} \in \{1, 2, 3, \dots\}$ firms, then given this sample of firms, we estimate their value following the same specification of the regression as in (5).

In this case, a Monte Carlo simulation of the model yielded no significant change in optimal policy: the distance from the -0.5% Δp policy to the apparent optimum policy obtain in the simulation (which was a slightly higher price of circa -0.1%) in terms of consumption equivalent variation was approximately 0.1% which is smaller the standard deviation for this set of Monte Carlo simulations.

B.4 Model with Homogeneous Industries

The quality-ladder literature includes papers related ours, such as Cavenaile et al. (2021). In this set of environments, industries are homogeneous: aggregate revenues of different industries are the same, and entry barriers for entering firms do not depend on the industry's mean productivity relative to the economy. Here, for comparison, we consider modifying our model to be consistent with this class of environments, demonstrating the quantitative importance of allowing industries to be interactively heterogeneous.

Consider a variation of our model with unit demand elasticity, and where the productivity of new entrants only depends on the industry's productivity (thus $b = 0$). To prevent the monopoly price from exploding to infinity (due to unit elastic demand), assume the household can produce the good at a constant marginal cost of $1/(1 - 1/s)$ times the monopolist's marginal cost. Since the monopolist's markup in the version with substitution elasticity s was $1/(1 - 1/s)$, this variation of the model matches the original model's monopoly markup.

As shown in Figure 2 and Table 9, removing industry heterogeneity in the model under the status quo merger policy yields an environment with many fewer mergers, a much lower exit rate, and where competition policy has much smaller effects. The average markup is lower, and the growth rate is slightly higher. This exercise clearly shows that industry heterogeneity has important quantitative implications for the model. The optimal policy also changes substantially and becomes much more restrictive if we remove industry heterogeneity from the model. In particular, the optimal policy implies a merger rate close to zero.

	Target	*Model*	*Model (HI)*
Annual growth rate of GDP per capita	$1.5 - 1.7\%$	1.61%	1.68%
Average markup (Lerner index)	$25 - 30\%$	27.5%	21.9%
Standard deviation of firm TFP	$10 - 15\%$	10.7%	12.4%
Firm exit rate	$3.5 - 4.0\%$	3.56%	2.51%
Rate of mergers	$\approx 4.5\%$	4.45%	1.39%
Mean value gain of mergers	$4 - 17\%$	15.2%	5.5%
Firm R&D expenditures/revenues	$2 - 5\%$	4.8%	3.3%
Mean number of firms		3.48	5.55

Table 9: Model with homogeneous industries (HI) compared to data and the model's output shows how equilibrium changes removing industry heterogeneity: far fewer exits and mergers occur, as firms' value gains from merging and the opportunity cost of exit are lower.