1 Model

This section presents a Schumpeterian model based on **?**, featuring growth through creative destruction by entrants, as well as the possibility for incumbent monopolist of researching a defensive technology that increases research costs for entrants. I first present a single-sector model to clarify the mechanism at play within each sector in the economy and study the properties of a constant-growth equilibrium analytically. I then move to consider a two-sector model, where each sector is identical to the single-sector model, and the supply of inventors is perfectly rigid, which shuts down within-sector misallocation occurring independently of inventors' movements across sectors. I show that increasing markups in one of the two sectors of the economy lead to a misallocation of R&D resources towards defensive innovation in the less competitive sector. Finally, I study the optimal allocation of R&D subsidies needed to achieve maximum growth in a calibration of the two-sector model that matches moments of the R&D distribution in 1997, the starting year for my empirical analysis. All omitted proofs are reported in Appendix **??**.

1.1 Single-sector Model

1.1.1 Preferences and production

Consider the following continuous time economy with a single final good. There is a representative household with King-Plosser-Rebelo preferences over consumption and R&D labor

$$\mathbb{E}_t \int_t^{\infty} \exp\left(-\rho\left(s-t\right)\right)\left(\ln C_s - \frac{\chi\left(L_s^{RD}\right)^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}}\right)\mathrm{d}s, \tag{1}$$

where ϕ is the Frisch labor supply. In addition, the representative household inelastically supplies L units of production labor.[1] The representative household owns a differentiated portfolio of all the firms in the economy, with rate of return r_t, and receives a wages w, w^{RD}, for each unit of production and research labor, respectively. I assume that the economy is closed and that the final good is only used for consumption, $C_t = Y_t$. The above utility function yields a standard Euler equation and R&D labor supply with Frisch elasticity φ.

The market structure in the model follows **?** and **?**. Accordingly, the consumption good in the economy, which I take as numeraire, is the unit-measure aggregate of products

$$\ln Y_t = \int_0^1 \ln y_t(i)\mathrm{d}i. \tag{2}$$

[1] While this assumption is not necessary for the results to hold, it simplifies the analysis considerably. In the following section, I will consider both production and research labor as given by a fixed endowment in the constant growth equilibrium of the economy. In that case, the assumption is equivalent to assuming that both labor endowments grow at a constant rate.

The market for each product $y_t(i)$ consists of an incumbent and a fringe of competitors. In what follows, I focus on a single market, dropping the argument i. Each firm j in the sector produces an undifferentiated good with the linear production technology:

$$c_{j,t} y_{j,t} = l_{j,t},$$

where $c_{j,t}$ denotes the labor requirement to produce a unit of output, and $l_{j,t}$ the production labor employed by the firm. Competitors have labor requirement $c_{e,t} = c_t$, while the incumbent faces a lower unit labor requirement $c_{I,t} = \frac{c_t}{\phi}$, with $\phi > 1$. Profit maximization by the incumbent gives an optimum limit price $p_t = w_t c_{e,t}$, which leads her to capture the entire market and act as a monopolist, charging a markup $\phi > 1$ on the marginal cost. The Cobb-Douglas assumption on the final good implies equilibrium normalized profits,

$$\frac{\Pi_t}{Y_t} \equiv \pi = \left(\frac{\phi - 1}{\phi}\right).$$

1.1.2 Innovation

Both incumbents and entrants can conduct innovation activity that, if successful, reduces their unit costs to

$$c_{I,t+\Delta_t} = \frac{c_{e,t}}{(1+\eta)\,\phi}, \quad \eta > 1$$

Here, η parametrizes the percentage increase in productivity for the innovating firm, relative to the technology previously operated by the incumbent. Whenever either the incumbent or an entrant realize an innovation, all other firms gain access to a technology with unit costs, $c_{e,t+\Delta_t} = c_{e,t} / (1+\eta)$. These assumptions imply that, if entrants realize an innovation, they outcompete previous incumbents and become the new monopolists. Displaced incumbents join the pool of entrants and from instant $t + \Delta t$ onwards operate the technology $c_{e,t+\Delta_t}$. [2] With this structure, the relative productivity of incumbents to entrants is fixed at ϕ regardless of the number of innovations realized, which allows a recursive formulation of the problem. I therefore drop time indexes in what follows.

Incumbents' and entrants' innovation differ in two respects. First, successful incumbents' R&D produces a *patent wall* of size $\omega > 1$, which decreases the success probability of entrants' innovations. Second, successful entrants' R&D results in an implemented innovation with certainty, while incumbents adopt new technologies with probability $\lambda \in [0,1]$. I introduce this parameter to allow for incremental incumbents' innovations. The lower λ, the lower the expected productivity gains from incumbents' innovations.

Following **?**, I assume that innovation investments consist in the choice of an arrival rate of new

[2] This amounts to assuming that the incumbent's technology becomes obsolete after displacement or that incumbents scrap the assets needed to operate the innovative technology upon destruction.

discoveries x_I, and that R&D costs are increasing and convex in this arrival rate:

$$C\left(x_I; w^{RD}\right) = \alpha_I \frac{x_I^\gamma}{\gamma} w^{RD}, \; \gamma > 1,$$

where the term $\alpha_I \frac{x_I^\gamma}{\gamma}$ indicates the amount of inventors that the incumbent needs to obtain innovations with a flow probability x_I, and w^{RD} is the wage paid to inventors. For simplicity, I assume that incumbents can only have one available innovation at a time. Incumbents can only erect *one* patent wall of size $\omega > 1$, and cannot invest in further innovation until their patent expires, which occurs at a rate δ.

Under these assumptions, incumbents' values at any given instant are just a function of the state of the patent wall in the product market they operate, $\Omega \in \{1, \omega\}$:

$$rV(1) - \dot{V}(1) = \max_{x_I} \left\{ \left(\frac{\phi - 1}{\phi}\right) Y - \alpha_I \frac{x_I^\gamma}{\gamma} w^{RD} + x_I \left(V(\omega) - V(1)\right) - x_{e,1} V(1) \right\}, \tag{3}$$

$$rV(\omega) - \dot{V}(\omega) = \left(\frac{\phi - 1}{\phi}\right) Y + \delta \left(V(1) - V(\omega)\right) - x_{e,\omega} V(\omega), \tag{4}$$

where $x_{e,1}$ and $x_{e,\omega}$ denote entrants' innovation intensities, r is the interest rate in the economy, and δ the rate of patent expiration. The first line displays the flow value to incumbents that operate in a market not protected by a patent wall. There, incumbents realize instantaneous profits $\left(\frac{\phi-1}{\phi}\right) Y$, and choose their innovation intensity x_I, taking the researchers' wage w^{RD} and the entrants' innovation intensity $x_{e,1}$ as given. If entrants are successful at rate $x_{e,1}$, incumbents are destroyed. If incumbents' innovation is successful at rate x_I, they obtain the patent wall ω, which grants them the protected value $V(\omega)$. When a patent wall is in place, incumbents realize the same flow of profits as in the unprotected state, since economy-wide spillovers imply that incumbents are unable to reap profits from implemented innovations. However, incumbents face a different entrants' innovation intensity, $x_{e,\omega}$, which is lower than $x_{e,1}$ due to the patent wall in place, as I will show below. Finally, incumbents in state ω face a flow probability δ that the patent wall is exogenously destroyed, in which case they transition back to the unprotected state. Under these assumptions, the optimal incumbent's R&D decision is given by

$$x_I = \mathbf{1}\left\{V(\omega) - V(1) > 0\right\} \left(\frac{V(\omega) - V(1)}{\alpha_I w^{RD}}\right)^{\frac{1}{\gamma - 1}}. \tag{5}$$

Following **?**, I assume that each market has a mass of atomistic entrants, indexed by j, who face innovation costs that feature congestion externalities

$$C\left(x_{e,\Omega,j}; w^{RD}\right) = \zeta \Omega x_{e,\Omega,j} x_{e,\Omega} w^{RD}.$$

In this specification, ζ parametrizes the inventor requirement to obtain a unit aggregate entrants' innovation rate when the market is not protected by patent walls, $\Omega = 1$. Individuals costs are linear in the total entrants' research intensity in the product market, $x_{e,\Omega} \equiv \int_{\mathcal{J}} x_{e,\Omega,j} \mathrm{d}j$. In other terms, individual entry costs increase with the aggregate entry rate. Successful entrants obtain a new unprotected technology, regardless of the state of the market that they target. Free entry implies that the optimal entry rate for each product market with patent wall Ω as:[3]

$$x_{e,\Omega} = \frac{V(1)}{\zeta \Omega w^{RD}}, \quad \Omega \in \{1, \omega\}. \tag{6}$$

This shows that defensive innovation reduces the entry rate by a factor ω.

1.1.3 Equilibrium with Constant Growth

The mass of protected and unprotected markets evolve according to:

$$\dot{\mu}_1 = -\left(x_I + x_{e,1}\right)\mu_1 + \delta\mu_\omega + x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1}, \tag{7}$$

$$\dot{\mu}_\omega = -\left(x_{e,\omega} + \delta\right)\mu_\omega + x_I\mu_1, \tag{8}$$

where $\mu_{e,\omega}$ and $\mu_{e,1}$ denote the mass of entrants targeting protected and unprotected markets, respectively. The interpretation is similar to Equations (3) and (3) . Similarly, the mass of entrants in each product market follows the laws of motion:

$$\dot{\mu}_{e,1} = -\left(x_{e,1} + x_I\right)\mu_{e,1} + x_{e,1}\mu_1 + \delta\mu_{e,\omega}, \tag{9}$$

$$\dot{\mu}_{e,\omega} = -\left(x_{e,\omega} + \delta\right)\mu_{e,\omega} + x_{e,\omega}\mu_\omega + x_I\mu_{e,1}, \tag{10}$$

The model is closed by production and R&D labor market clearing read:

$$L = \int_0^1 l(i)\mathrm{d}i, \tag{11}$$

$$L^{RD} = \zeta\left(\omega x_{e,\omega}\mu_{e,\omega} + x_{e,1}\mu_{e,1}\right) + \alpha_I \frac{x_I^\gamma}{\gamma}\mu_1. \tag{12}$$

The definition of the constant growth equilibrium and its properties follow.

Definition 1.1 (Constant Growth Equilibrium)**.** A constant growth equilibrium is a sequence of values $\{V_t(1), V_t(\omega)\}$, production workers' and inventors' wage sequences $\{w_t^{RD}, w_t\}$, and incumbents' and entrants' R&D decisions $\{x_{I,t}, x_{e,1,t}, x_{e,\omega,t}\}$ such that, given an endowment of production labor, L, L^{RD}:

[3] See **?** for more details.

(i) incumbents maximize values (3) and (4), taking entrants R&D decisions as given; (ii) entrants' R&D decisions satisfy (5) and (6) taking $V_t(1)$ as given; (iii) the distribution of incumbents and entrants across protected and unprotected markets is constant, $\dot{\mu}_1 = \dot{\mu}_\omega = \dot{\mu}_{e,1} = \dot{\mu}_{e,\omega} = 0$ in Equations (7)-(10); (iv) values in each instant are determined by (3) and (4); (v) consumers maximize utility (1), choosing consumption and R&D labor optimally; (vi) labor markets clear according to (11) and (12); (vii) product markets clear, $C_t = Y_t$; and (viii) aggregate output (2) grows at the constant rate, $g \equiv \dot{Y}_t / Y_t$.

Proposition 1.2 (Existence and Uniqueness of the Constant Growth Equilibrium)**.** *For any endowments of production labor L, there exists a unique constant growth equilibrium. Denoting optimal incumbents' and entrants' choices as $x_I^\star, x_{e,\omega}^\star, x_{e,1}^\star$, and the masses of incumbents and entrants across states as $\mu_1^\star, \mu_\omega^\star, \mu_{e,1}^\star, \mu_{e,\omega}^\star$, the constant growth rate of the economy is given by*

$$g = \eta\left[x_{e,\omega}^\star \mu_{e,\omega}^\star + x_{e,1}^\star \mu_{e,1}^\star + \lambda x_I^\star \mu_1^\star\right],$$

and inventors' productivity reads

$$\frac{g}{L^{RD}} = \eta \frac{x_{e,\omega}^\star \mu_{e,\omega}^\star + x_{e,1}^\star \mu_{e,1}^\star + \lambda x_I^\star \mu_1^\star}{\zeta\left(\omega x_{e,\omega}^\star \mu_{e,\omega}^\star + x_{e,1}^\star \mu_{e,1}^\star\right) + \alpha_I \frac{(x_I^\star)^\gamma}{\gamma} \mu_1^\star}.$$

The expressions in this proposition clarify that an equilibrium increase in the mass of entrants in protected markets, $\mu_{e,\omega}^\star$ leads to a fall in inventors' productivity. Indeed, while a unit of aggregate research intensity produces the same growth across unprotected and protected markets, the research unit labor requirement is higher than in unprotected markets by a factor of ω, as can be seen comparing the numerator and denominator of inventors' productivity. Since incumbents' research effort acts to raise $\mu_{e,\omega}^\star$, *ceteris paribus* inventors' productivity declines when incumbents employ a larger share of inventors.[4] As the following proposition shows, higher markups unambiguously increase research efforts by incumbents and entrants, as well as the share of R&D labor accruing to incumbents.

Proposition 1.3 (Effects of Markup Increases on Innovation)**.** *Suppose that defensive research is effective, $\omega > 1$. The constant growth equilibrium features positive incumbents' research, $x_I^\star > 0$; markup increases raise both incumbents' and entrants' research effort*

$$\frac{\partial x_I^\star}{\partial \phi} > 0, \; \frac{\partial x_{e,\omega}^\star}{\partial \phi} > 0 \; \frac{\partial x_1^\star}{\partial \phi} > 0.$$

[4] In a previous version of this paper, I prove that a sufficient condition for $\mu_{e,\omega}^\star$ to increase with markups is that the research intensity of incumbents is more elastic than entrants', a condition which is verified in all the numerical simulations I explored.

If labor supply is elastic, the incumbents' inventor share increases with markup

$$\frac{\partial \frac{L_I}{L^{RD}}}{\partial \phi} = \frac{\partial \left(\alpha_I \frac{x_1^{\star\gamma}}{\gamma} \mu_1^{\star} / L^{RD} \right)}{\partial \phi} > 0.$$

Higher markups raise the value of monopolistic positions, propelling entrants' and incumbents' research effort, and tilting the distribution of inventors toward incumbents. Importantly, this holds only if defensive R&D is effective, showing the importance of this channel to reproduce the empirical findings in Table **??**. Note also that when inventors' supply is inelastic, wage effects fully offset the increase in labor demand, and equilibrium uniqueness implies a fixed allocation of inventors across incumbents and entrants.

1.2 Calibration and Policy

In this section, I calibrate a two-sector extension of the model presented in the previous Section, with two main objectives. First, I want to analyze misallocation *across* sectors, and show that, under a realistic calibration, this extension can qualitatively reproduce the main findings of the empirical analysis. I focus on the benchmark with *fixed* inventor supply where markups have no effect on inventors' productivity within sectors. This choice excludes that my findings are driven by within-sector misallocation alone. Second, I show that growth is maximized when R&D subsidies are allocated to entrants in the less competitive sector.

1.2.1 Model description

The consumption good in the economy is given by the Cobb Douglas aggregate:

$$\ln Y_t = \beta_1 \ln Y_{1,t} + \beta_2 \ln Y_{2,t}, \quad \beta_1 + \beta_2 = 1$$

where $Y_{1,t}$, $Y_{2,t}$ are produced as in Section 1.1.1, and the markup parameter, ϕ, is allowed to vary across the two sectors. The household side of the economy is unchanged relative to the one-sector model. In this section, I assume a fully rigid supply of inventors fixed at $L^{RD} = 100$, allowing a clean interpretation of the results in this section as arising from inventors' mobility across sectors. As the previous section has shown, a rigid inventors' supply excludes reallocation of inventors within sectors in the absence of cross-sector mobility.[5]

The rest of the model is unchanged relative to the previous section, except that now aggregate labor demands are given by the sum of each sectors' demand, and, due to the Cobb-Douglas assumption,

[5] When aggregate inventors' supply is elastic, the misallocation effects of increased markups are larger, since the allocation of inventors becomes less efficient both within and across sectors.

the growth rate of the economy is the average sector growth rate weighted by β_i. Appendix ?? reports the derivations for the two-sector model and a complete description of the equations characterizing the equilibrium.

1.2.2 Calibration

I calibrate my model in order to match features of the R&D distribution and concentration around 1997, the starting year for my analysis. This approach provides conservative parameter choices to analyze the model. Feeding observed changes in markups, inventor productivity falls by about 2.5% over the period 1997-2012, consistent with the lower bounds of my estimates.[6] This calibration therefore produces a lower bound for the impact of optimal R&D subsidies.

The upper part of Table 1 displays my choices for parameters calibrated externally. I set the discount rate to 4%, which, together with a 3% growth for my sample in 1997, implies a value for the real interest rate of 7%, in line with the long-run average before 1997. The share of value added of each sector, β comes from estimates of the Lerner Index in manufacturing, constructed using NBER-CES data as described in Appendix ??. About half of the sectors (weighted by sales) for which I have data saw an increase in the Lerner Index over the period, which justifies setting $\beta_1 = \beta_2 = 0.5$. Since I only have the Lerner Index for about half of the sectors, I rely on the extensive literature estimating markups to set a value of $\phi = 1.08$.[7] As standard in the literature (see e.g., ?), I set the curvature of the incumbents' cost function relying on estimates by ?. I choose the lower bound of these estimates to minimize the asymmetry of innovation costs between incumbents and entrants, as more convex incumbents' costs mechanically make their research less effective than entrants. The rate of patent expiration comes from the legislative framework in the US, as established by the Uruguay Round Agreements Act of 1994. Since λ measures how radical are incumbents' innovations relative to entrants', I set $\lambda = 0.785$, consistent with an internal patent share of 21.5% estimated by ?. Turning to the value of blocking patents, parametrized by ω in my model, I rely on estimates by ? and ?, who employ merger data to obtain the effect of pre-emptive patents on the value of acquired firms. Both their estimates imply an elasticity of firm's values to the share of patents with pre-emptive value of more than one. This implies that a firm with a patent portfolio composed exclusively of defensive patents is valued on average twice as much as one with only patents that have no pre-emptive value, implying $\omega = 2$. As shown in the proof of Proposition 1.2, the percentage increase in firm value when acquiring a defensive patent is capped at $\omega - 1$, implying an elasticity of firm value to patents of at most 1. I also include R&D subsidies, modeled as a percent subsidy on inventors' wages, s, and corporate taxes applied to firms instantaneous profits, τ, parametrized as in ?.

[6] Column (4) in the upper panel of Table ?? implies a lower bound for the fall in inventor productivity of about 1.5%, while the lower panel implies a fall in inventor productivity of at least 4.8%. The 2.5% fall in my calibration is in between these two lower bounds.

[7] I follow ?, who calibrate the same parameter using the midpoint of estimates provided in ? and ?.

Table 1: Parameter Values and Sources

Parameter Name	Symbol	Value	Source/Target
Discount rate	ρ	.04	Annual real rate ≈ 7% before 1997
Value Added Share	β	.5	Share of sectors with ↑ Lerner Index
Average Sectors' Markup	ϕ	1.08	**?**
Innovation Cost Curvature	γ	1/.6	Lower bound in **?**
Intensity of Patent Expiration	δ	.05	Uruguay Round Agreements Act (1994)
Share of Implemented Innovations	λ	.785	**?**
Value of Blocking Patents	ω	2	**?**
R&D subsidy	$s_I = s_e$	19%	**?**
Corporate tax rate	τ	23%	**?**
Incumbent Costs	α_I	21.97	Top 10% Firms' Inventor Share, 1997: 30.3%
Entrants' Costs	ζ	4.75	Business R&D Share over GDP, 1997: 1.81%
Innovation Step	η	0.0047	Output per Worker Growth, 1997: 3.03%

The bottom part of Table 1 describes my choices for the remaining parameters, which govern the scale of R&D and the growth rate in the economy. I set the incumbents' and entrants' R&D cost scale, α_I and ζ, to match the share of inventors employed by incumbent firms in 1997 and the R&D business spending as a percent of GDP, as reported by the National Science Foundation. Intuitively, the two cost parameters jointly determine the overall R&D spending in the economy, while their relative value determines the distribution of R&D spending in equilibrium. Given the estimates for α_I and ζ, I set η to match the growth in output per worker for the sectors considered in my analysis in 1997, 3.03%. All targets are matched almost exactly.[8]

1.2.3 Comparative Statics in General Equilibrium

Figure 1 displays the comparative statics for an increase in markup in sector 2, while leaving the sector 1's markup unchanged. The graphs compares the aggregates of interest across different constant growth equilibria, and each figure reports the markup of sector 2 relative to sector 1 on the x-axis.

An increase in the relative markup of sector 2 leads to a pronounced reallocation of inventors away from sector 1. In sector 2, incoming inventors are allocated disproportionately to incumbents, who expand their share of researchers relative to entrants. Computing the Lerner Index on NBER-CES data as described in Appendix **??** reveals that the markup gap between more concentrated and less concentrated sectors has increased by about 20% over the period of interest. This implies a fall in inventors' productivity of 2.5% compared to the benchmark where the two sectors have the same competitive structure. Since the supply of inventors is fixed at $L^{RD} = 100$, this also results in a 2.5% fall in GDP growth, about 0.075pp. This estimate is in between the lower bound of 0.13pp implied by my estimates in the lower panel of Table **??** and the lower bound of .03pp implied by the upper panel. Assuming an inelastic labor supply mutes the response of inventors' productivity to increases

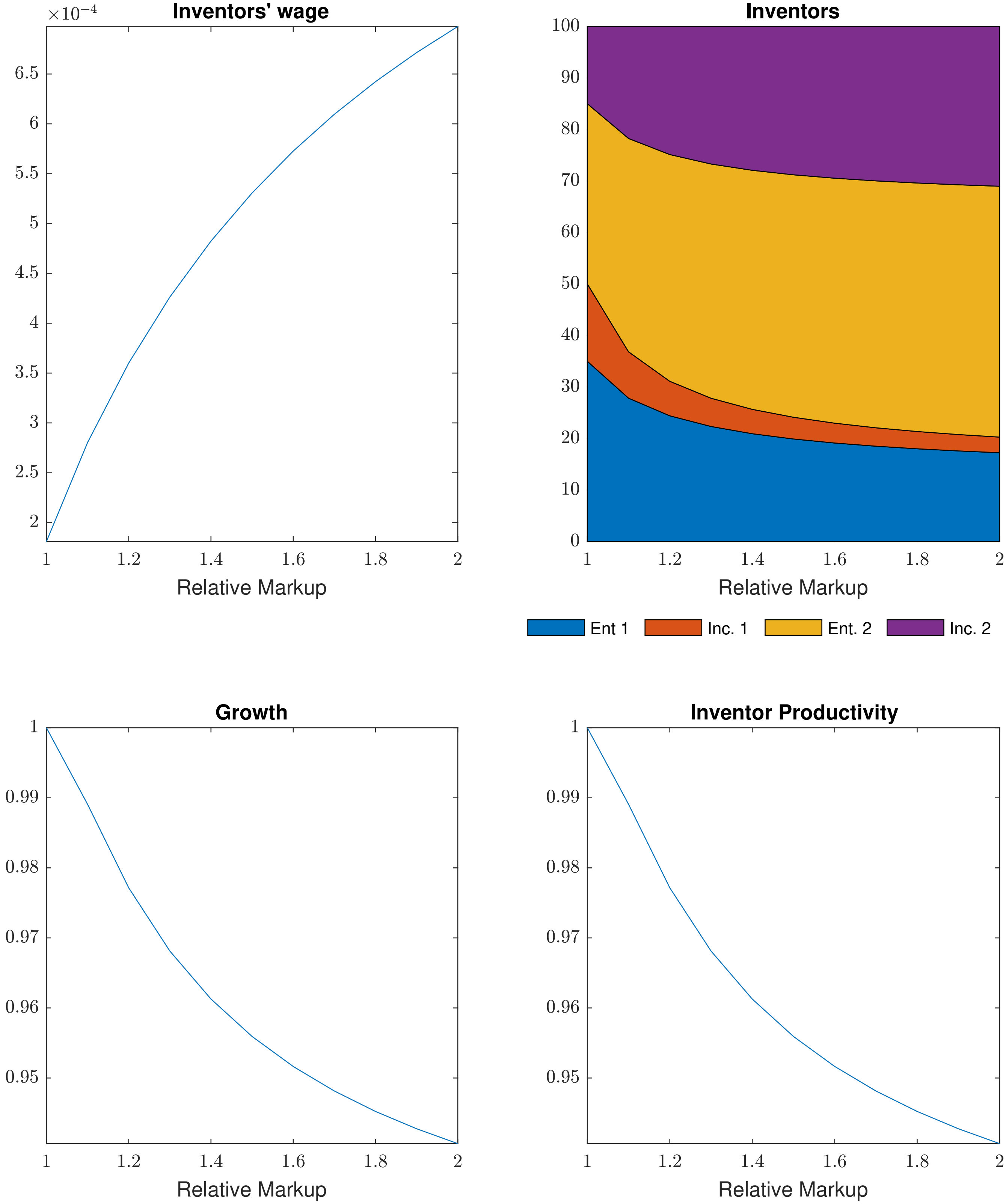
[8]The average percentage point deviation of moments in the model from their empirical targets is less than 10^{-6}.

in the markup, so it is reasonable to expect the model in this section to understate the productivity effects of increased concentration. As discussed above, this benchmark is desirable since it shuts down productivity effects unrelated to reallocation.

Figure 1 also shows that inventors within sector 1 reallocate toward entrants. This is because a lower entry threat in this sector reduces the incentives for defensive innovation. In other terms, the incentives to conduct defensive innovation increase when a larger number of inventors is employed in the sector. Therefore, while the movements of inventors from sector 1 to sector 2 are overall detrimental to growth, they are not for R&D productivity in sector 1. However, overall growth is lower since less R&D resources are available to this sector in equilibrium. Thus, reallocation away from competitive sectors has both costs–a reduction in sectoral growth–and benefits, coming from a more efficient distribution of resources within this sector.

This comparative static exercise also clarifies how defensive innovation undergirds misallocation across sectors. In the absence of defensive innovation, inventors just reallocate across sectors, leaving productivity unaffected. As a result, overall growth is also unchanged, since the Cobb-Douglas assumption with $\beta = 0.5$ gives aggregate growth as the simple average of growth in the two sectors.

Figure 1: Comparative Statics in Sector 2's Markup Relative to Sector 1 in the Two-Sector Model, Economy Aggregates



Note: This figure reports the comparative statics for normalized profits, inventors, growth and inventor productivity in the two-sector model. In all figures, the x-axis reports the markup of sector 2 relative to sector 1. The parameters used to produce this figure are reported in Table 1.

1.2.4 Growth-Maximizing Policy

I now turn to calculating the combination of R&D subsidies that maximizes growth. I assume that the planner wishes to maximize growth under a set of different constraint on the instruments available. In particular, I assume that the planner cannot alter the nature of innovation, that is, the planner cannot distinguish productive from unproductive projects, and cannot forbid registering defensive patents. In this model, eliminating protection for incumbents would lead to a first-best where only entrants conduct R&D and reallocation could only promote growth, as discussed in the previous section.

I start from the 2012 equilibrium of my model economy, where the gap in markups between sector 2 and sector 1 is 20%, and all firms receive a 19% subsidy to inventors' wages and incur a 23% tax on profits. I then evaluate numerically three cost-neutral alternatives, that is, I constrain the planner to leave the expenditure on R&D subsidies as a percentage of GDP fixed at the 2012 benchmark. In the first scenario, the planner is allowed to distribute subsidies freely and can condition the allocation on both the state of the market (protected or unprotected) and the identity of the receiving firm (entrant or incumbent). In the other two scenarios, I only allow the planner to act on one of these dimensions at a time. That is, the planner can either control the cross-sector distribution of funds, but not the allocation across incumbents and entrants, or vice versa.

The results of this exercise are presented in Table 2. The 2012 equilibrium is reported in Columns 1 and 2. For reference, the 1997 calibrated model has two identical sectors, which share the stock of inventors equally. Within each sector incumbents have 30.3% of the overall inventors employed, and GDP growth is 3% per annum, as reported in Table 1. In the 2012 baseline, the distribution of inventors is tilted toward the second sector, where markups have increased. This results in a fall in annual GDP growth of .07pp, about 2.5% of the 1997 benchmark. As shown in the graphs above, this new equilibrium sees a larger share of inventors allocated to incumbents in the second sector, which increases its growth relative to its more competitive counterpart. However, productivity declines because of higher defensive innovation by incumbents. Columns 3 and 4 report the optimal cost-neutral R&D subsidies chosen by a growth-maximizing planner. Somewhat surprisingly, the most efficient allocation of funds turns out to be a subsidy to entrants in the more concentrated sector only. Indeed, defensive innovation is inefficient because it makes entrants' R&D less productive. This is the main friction that the growth-maximizing planner wishes to remove. As discussed above, the outflow of inventors from sector 1 increases inventor productivity, as lower R&D by entrants depresses defensive innovation by incumbents. It is therefore undesirable to reallocate inventors to entrants in sector 1, where barriers to entry are now naturally lower. Conversely, the optimal policy acts directly on the higher barriers now present in sector 2, subsidizing inventors' wages for entrants. Consistent with this argument, growth is not maximized when the planner allocates R&D subsidies to a single sector, without condition on the identity of the firm. This scenario is reported in columns 5 and 6. The planner subsidizes the more competitive sector 1, which brings annual growth up to 2.99%, recovering most of the lost ground relative to the 1997 benchmark. However, subsidies now make defensive innovation cheaper for incumbents, as well as more attractive due to increased entry. If a sector-specific subsidy to entrants is politically unfeasible, a viable alternative is a blanket entry subsidy as reported in Columns 7 and 8. The resulting growth in annual output of 3.38% exceeds the starting 1997 equilibrium.

To conclude, the policy analysis suggests that entry subsidies are the most effective policy to counter the friction introduced by defensive innovation in this model economy. The best approach is to subsidize entrants in less competitive sectors, where this friction is most pronounced, increasing growth by 0.5pp per annum. A more feasible uniform R&D subsidy to entrants produces quantitatively similar effects. Conversely, sector-specific subsidies to reallocate inventors to more competitive sectors are less effective, since incumbents use them to conduct pre-emptive innovation, precisely the source of inefficiency that the planner wishes to contrast.

Table 2: Comparison of R&D Policies in the Two-Sector Model

	Baseline		Optimal Cost-Neutral		Cost-Neutral Sector		Cost-Neutral Entry	
	Sector 1 (1)	Sector 2 (2)	Sector 1 (3)	Sector 2 (4)	Sector 1 (5)	Sector 2 (6)	Sector 1 (7)	Sector 2 (8)
R&D Subsidies:								
s_I	19%	19%	0%	0%	46.17%	0%	0%	0%
s_e	19%	19%	0%	41.78%	46.17%	0%	29%	29%
Aggregates:								
L_I^{RD}	6.70	24.87	6.37	15.95	10.83	19.51	4.83	18.45
L_e^{RD}	24.41	44.02	23.87	53.81	30.24	39.42	27.41	49.30
L_{TOT}^{RD}	31.11	68.89	30.25	69.75	41.07	58.93	32.25	67.75
Sector Growth	2.12%	3.74%	2.08%	4.78%	2.61%	3.36%	2.45%	4.31%
GDP Growth	2.93%		3.43%		2.99%		3.38%	

Note: The figures reported in this table give the optimal allocation of R&D subsidies and the resulting aggregate outcomes for a planner wishing to maximize aggregate growth in the economy. The column headings refer to the various scenarios described above. “Baseline” refers to the subsidy allocation reflecting the 2012 equilibrium, where subsidies do not condition on sectors or the position of firms within sectors; “Optimal Cost-Neutral” refer to the scenario where the planner is allowed to freely allocate R&D subsidies subject to the constraint that overall R&D subsidy expenditure as a percentage of GDP is held fixed at its 2012 benchmark; “Cost-Neutral Sector” consider a scenario where the planner can choose which sector to allocate funds to, but not which firms within the sector should receive the subsidy; “Cost-Neutral Entry” computes the optimal universal entry subsidy, under the assumption that the planner cannot condition its reception on the sector firms operate in.