Technological Progress and Rent Seeking *

`(preliminary and incomplete)`

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Abstract

We model firms' optimal allocation of resources between surplus-creating (a.k.a., productive) activities and surplus-appropriating (a.k.a., rent-seeking) activities. We show that economy- or industry-wide technological progresses, such as the recent improvements in processing big data, induce a disproportionate and socially inefficient allocation of resources towards rent seeking. As technology improves, firms lean more on rent seeking to generate their profits, endogenously reducing the impact of technological progress on economic progress and inflating the price of resources that can either be used for rent seeking or production.

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1 Introduction

Standard growth theories show the importance of technological progress that improves firms' productivity in generating long-term economic growth. Technological advancements embodied in capital (such as improvement of materials, robotization, automation, etc), in labor (higher human capital and knowledge), and in methods used to combine inputs (organizational and human resource managements) can all promote the growth of an economy. The literature is, however, mostly silent about the role of these technological advancements on rent-seeking behavior, and the incentives to use the improved technology to appropriate others' surpluses. How does the acknowledgment that firms may allocate efforts and resources to appropriate surplus from others affect our understanding of the relation between technology and economic growth?

In this paper, we model firms' optimal allocation of resources between surplus-creating (i.e., productive) and surplus-appropriating (i.e., rent-seeking) activities, and show that a technological breakthrough that improves productivity in an industry induces a disproportionate and socially inefficient allocation of resources to surplus-appropriating activities. While this prediction would be trivial if restricted to situations where technology is mostly relevant in facilitating surplus appropriation, it holds even when the productivity gains from technological progress are far larger for surplus-creating activities than surplus-appropriating activities. In fact, as long as technological progress ameliorates *to some extent* firms' ability to appropriate their rivals' surplus, firms respond to this progress by investing disproportionately more resources in those activities.

Intuitively, when a technological improvement increases the size of the economic surplus created by firms through higher industry-wide productivity, the incentives each firm faces to do rent seeking also go up simply because the surplus that can be appropriated from rival firms is now higher. However, if this technological improvement also increases a firm's ability to appropriate a larger share of the economic surplus, even just a little bit, the incentives to appropriate the larger surplus increase disproportionately more than the incentives to create additional surplus. Thus, as technology improves, the economy moves gradually from a *productive economy* to a *rent-seeking economy*, in which any technological advancement translates less into higher output. Due to this overinvestment in surplus-appropriating activities, aggregate output is a concave, potentially non-monotone function of technology quality.

Our analysis delivers quantitative implications not only for the amount of rent-seeking activities performed in the economy, but also for the price of the resources that are inefficiently allocated. As technology improves, and the economy moves towards a rent-seeking economy, the disproportionate allocation of resources to non-productive activities can raise the price of those resources above what it would be in a benchmark economy without rent seeking. In this sense, the effects of technology through rent seeking not only manifest themselves in a higher share of the economy's resources being inefficiently allocated to rent-seeking activities, but also in a larger price paid for the resources needed to perform these activities (which often happen to be resources that could also be used to create more social surplus).

In our model, rent-seeking activities allow firms to appropriate a larger share of the surplus produced by other firms. Thus, our model focuses on rent-seeking activities that become more attractive as the rest of the economy performs better. Examples of activities that match this description include suing rich parties, imitating the innovations of successful rivals, and lobbying for excessive payments from the government (usually funded by taxes paid by the rest of the economy). However, some activities related to making a firm more competitive vis-à-vis its industry do not typically match this description. For example, if poaching customers from an industry-leading firm requires offering better products and services that customers value more than what the industry leader offers, clearly these practices do not constitute rent seeking. Moreover, poaching customers by making large investments in "predatory" marketing and advertising might constitute an inefficient use of resources, but unlike the surplus-appropriating activities in our model, these practices become more challenging, and thereby less attractive, when the industry leader is more successful at fulfilling its customers' needs. Our results speak to firms' allocation of resources to activities that are beneficial mainly because they allow to expropriate a greater share of the surplus that others have created – when others become more productive, the rewards associated with performing these activities also increase.

The recent technological wave led by improvements in data collection, storage, and processing, for instance, has improved dramatically the use of information to, not only facilitate the creation of surplus but also in some case to appropriate the surpluses produced by others. We can think of several examples of how technological progress has benefitted rent-seeking activities, in addition to benefitting productive activities. A notable example is the use of new technologies both to innovate, through research and development, and to imitate other firms' innovations. Big data, machine learning, artificial intelligence, and other improvements in the use and processing of information have sped up and enhanced the creation of new drugs or new material. However, they also sped up and enhanced the ability to reverse engineer and copy rivals' innovations. Our paper shows that there is a disproportionate incentive to assign resources to the strategy of imitation and surplus appropriation, even if technology facilitates innovation and surplus creation in a much stronger way. Legal services, tax reporting services, and lobbying efforts often strive on redistributing surplus across agents. Our model suggests that as long as technological improvements increase efficiency when providing these services, as is the case with big data and information processing, then a disproportionate amount of resources will be allocated to these activities. Again, the larger the pie generated by technological improvements, the larger the incentives to appropriate a large share of it. In the finance industry, big data processing not only improved the allocation of credit and the monitoring of funded projects to generate a more efficient use of idle capital, but it also facilitated various speculative activities, such as high-frequency trading in centralized stock markets. Regardless of the impact of technology on the credit-related activities, if a technological innovation improves the productivity of surplus-appropriating activities like speculative trading by any margin, we should observe a larger overinvestment of resources in the latter type of activities and an inflated price needed to acquire the relevant resources. Overall, our results highlight an understudied dampening effect of rent seeking on the role of technological progress on economic progress. As this dampening effect grows with technology, our paper highlights the heightened relevance of regulating, taxing, and/or curbing rent-seeking activities.

Literature review. This paper contributes to the literature connecting technological improvements with economic growth. Since the celebrated growth model of Solow (1957), it is well understood that long-term economic growth, in the balance-growth path, is purely driven by the growth rate of productivity, determined by technological improvements. Our work suggests that the connection between technological improvements and economic growth becomes weaker over time in the presence of rent-seeking opportunities. In this sense, rent seeking should be added to the elements commonly identified in the literature as part of the Solow residual, such as spillovers, increasing returns, taxes, and various types of factor inputs, as highlighted by Barro (1999).

The paper also contributes to the literature on rent seeking. The seminal analysis by Murphy, Shleifer, and Vishny (1991) study the occupational choice of agents between productive and rent-seeking sectors, highlighting how this choice depends on the returns to ability and scale in each sector. When the returns from rent seeking are increasing in the intensity of rent-seeking activities, multiple equilibria might exist and agents' occupational choices may lead to lower growth, a channel that is further highlighted in Murphy, Shleifer, and Vishny (1993). In order to keep the model homogenous in the state of technology, Murphy, Shleifer, and Vishny (1991) assume no technological progress in rent seeking, thereby ensuring that the allocation of workers is unaffected by technological innovation. Instead, by allowing technological progress to affect all types of activities, we study how technological progress translates into economic growth and show how firms' allocation of resources lean further towards rent seeking as technology improves. While Baumol (1990) and Murphy, Shleifer, and Vishny (1991, 1993) all make the case that rent seeking slows economic growth, our paper highlights the impact of technological progress on the equilibrium level of rent-seeking activities in the economy, and as a result, it allows us to understand long-term trends in rent seeking and economic growth.

Our results about the price of resources when rent seeking becomes more prevalent is also related to the literature on superstars, such as Rosen (1981), in which the price of factors of production may be larger than their productivity. In our setting we obtain this result by the more extensive use of resources in, nonproductive, rent-seeking activities. Philippon and Reshef (2012) and Célérier and Vallée (2019) document the large increase in wages paid to financial workers. While Philippon (2010), Glode, Green, and Lowery (2012), Fishman and Parker (2015), and Glode and Lowery (2016) propose models in which resources are overinvested in financial activities that do not benefit society, our paper shows how the scale and the compensation associated with these activities may have been caused by firms' optimal re-allocation of resources in response to a wave of technological innovations.

Finally, an important discussion about rent seeking has focused on the activities that relate to obtaining favors or privileges from the public sector. An example is the lobbying efforts and their effects on segmented labor markets through public sector employment, as highlighted by Gelb, Knight, and Sabot (1991). Our insights can be extended easily to the presence of a public sector, with firms disproportionately allocating resources to rent seeking activities that become more useful as the economy becomes larger, and as such the public sector too.

2 Model

Suppose a set of firms $i \in I$. Each firm has a positive supply b_i of resources, from which the firm can use a quantity $s_i \geq 0$ to *create (social) surplus* according to a production function $\pi_i(s_i)$, or to use a quantity $x_i \geq 0$ to *appropriate surplus* from extracting a fraction $\alpha_i(x_i) \in [0,1]$ of a rival firm's surplus, such that $s_i + x_i \leq b_i$. (To fix ideas, it might help to think of these resources as labor, and each firm chooses how to allocate their workforce across activities.) For simplicity, assume for now that firm i has a single rival $j \neq i$ from which it can appropriate surplus, and vice-versa. Firm i's payoff is then given by:

$$\pi_i(s_i) \cdot [1 - \alpha_j(x_j)] + \pi_j(s_j) \cdot \alpha_i(x_i). \tag{1}$$

For now, the only restrictions we impose on the model is that, for all $i \in I$, $\pi_i(\cdot)$ and $\alpha_i(\cdot)$ are increasing, concave functions and $\alpha_i(\cdot) \in [0,1]$.

Firm i finds it optimal to allocate its resources to satisfy the first-order condition:

$$\pi_i'(s_i) \cdot [1 - \alpha_j(x_j)] = \pi_j(s_j) \cdot \alpha_i'(x_i). \tag{2}$$

In order to capture technological progress, we assume here that each firm's production function $\pi_i(\cdot)$ and $\alpha_i(\cdot)$ can be decomposed into a firm-specific technological parameter and a concave function of the resources the firm invests in that specific activity. That is, we let $\pi_i(s_i) \equiv \phi_{y,i} \cdot y(s_i)$ and $\alpha(x_i) \equiv \phi_{a,i} \cdot a(x_i)$. This is the same as assuming that increases in productivity comes from a technological change improving *total factor productivity*. Later, in the robustness section, we will show that our insights also apply to a *factor-augmenting* technological change as long as production functions adopt a standard Cobb-

Douglas specification.

The first-order condition under this assumption becomes:

$$\phi_{y,i} \cdot y'(s_i) \cdot [1 - \phi_{a,j} \cdot a(x_j)] = \phi_{y,j} \cdot y(s_j) \cdot \phi_{a,i} \cdot a'(x_i). \tag{3}$$

This first-order condition captures quite natural implications. Ceteris paribus (including keeping firm j's actions fixed), when firm i becomes individually more productive in creating surplus (i.e., $\phi_{y,i}$ increases), firm i finds it optimal to allocate more resources towards surplus-creating activities. When instead firm i becomes individually more productive in appropriating surplus from the other firm (i.e., $\phi_{a,i}$ increases), it finds it optimal to allocate more resources towards surplus-appropriating activities. Together, we get the natural implication that each firm responds to a firm-specific technological advancement by tilting its allocation of resources towards the activities whose productivity benefits most from the advancement. Again, this logic holds in partial equilibrium and in response to individual improvements in technology. In the following sections, we study first the reaction of both firms when hit simultaneously by an industry-wide technological advancement, and then we consider these insights in general equilibrium.

3 Industry-Wide Technological Progress

We now investigate how firms' resource allocation is impacted by technological progress that affects firm i and its rival(s) in the same way. In contrast to the earlier analysis, we will now account for the fact that, in equilibrium, a firm has to react to the best response of its rival(s). In particular, we set $\phi_{a,i} = \phi_{a,j} = \phi_a$ and $\phi_{y,i} = \phi_{y,j} = \phi_y$. With these industry-wide parameters, we can simplify firm i's first-order condition as:

$$y'(s_i) \cdot [1 - \phi_a \cdot a(x_j)] = y(s_j) \cdot \phi_a \cdot a'(x_i). \tag{4}$$

Interestingly, the industry-wide productivity parameter associated with surplus creation, ϕ_y, disappears from the first-order condition. Thus, the optimal allocation of resources is unaffected by any industry-wide improvement in the productivity of firms' surplus-creating activities. The reason for this is that this type of technological progress boosts a firm's rewards to surplus creation in the same proportion it boosts the rewards from appropriating its rival's (now larger) surplus.

On the other hand, the industry-wide productivity of surplus-appropriating activities, ϕ_a, still enters the first-order condition. Any technological progress that increases ϕ_a results in a larger share of the firm's resources being allocated to surplus appropriation. Ceteris paribus, a higher ϕ_a means that the right-hand side of (4) is lower while the left-hand side is higher. Therefore, firm i's optimal allocation of resources requires a smaller s_i and a larger x_i in response to any technological progress that boosts the productivity of surplus-appropriating activities (even if this technological progress also boosts the productivity of surplus-creating activities).

3.1 Allocation of resources

While predicting a firm's response to a change in industry-wide productivity levels is easy when holding its rival's allocation of resources fixed, what happens in equilibrium is not as immediate. Since firm i is expected to tilt its allocation of resources more towards surplus appropriation in response to technological progress (and this investment will gain in productivity), firm j assigns a lower marginal benefit to creating surplus. On the other hand, the effect of technological progress on the marginal benefit of appropriating firm i's surplus combines a decrease in resources invested by firm i with a higher productivity per unit invested.

We consider next a symmetric equilibrium, so we dispense from the sub-indices i and j and consider any pair of symmetrically impacted and behaving firms. Equation (4) can then be written as:

$$y'(b-x^*)\cdot[1-\phi_a\cdot a(x^*)]-y(b-x^*)\cdot\phi_a\cdot a'(x^*)=0. \tag{5}$$

If we differentiate the left-hand side of the first-order condition in (5) by x^*, we get:

$$-y''(b-x^*)\cdot[1-\phi_a\cdot a(x^*)]-y(b-x^*)\cdot\phi_a\cdot a''(x^*), \tag{6}$$

which is strictly positive whenever $a(\cdot)$ is strictly concave or $y(\cdot)$ is strictly concave and $\alpha(x^*)$ remains a fraction smaller than 1. Thus, under fairly standard assumptions, the first-order condition in (5) can only be satisfied with one level of x^* and, as a result, there exists only one symmetric equilibrium.

By applying the implicit function theorem to the first-order condition in (5), we can solve for how a marginal change in ϕ_a would affect the equilibrium investment in surplus appropriation x^*:

$$\frac{\partial x^*}{\partial\phi_a}=-\frac{y'(b-x^*)\cdot a(x^*)+y(b-x^*)\cdot a'(x^*)}{y''(b-x^*)\cdot[1-\phi_a\cdot a(x^*)]+y(b-x^*)\cdot\phi_a\cdot a''(x^*)}. \tag{7}$$

This expression is strictly positive whenever $a(\cdot)$ is strictly concave or $y(\cdot)$ is strictly concave and $\alpha(x^*)$ remains a fraction smaller than 1. Thus, under the same fairly standard assumptions as above, technological progress is expected to lead to more (socially inefficient) investment of resources in surplus appropriation. Yet, the surplus created by each firm, i.e., $\pi(s^*)=\phi_y\cdot y(s^*)$, might still increase with technological progress that significantly improves the productivity of surplus-creating activities, ϕ_y. We will later revisit these implications by parameterizing the model by assigning standard functional interpretations.

Notice, importantly, that the allocation of resources between surplus-creating and surplus-appropriating activities only depends on the absolute productivity of the latter, regardless of the level of the former. This can be easily seen in equation (5), which is independent of ϕ_y, the level of surplus-creating productivity.

3.2 Price of resources

Now, we assume that the firm has to compete for resources, that is, they do not have a budget b of resources but instead they have to pay for each unit of resources. We assume that the set of firms I competing for these resources is large enough such that each firm bids competitively for the same supply of resources.[1] In that case, the equilibrium price of resources, which we denote by w^*, is determined by the marginal benefit of investing more resources in either type of activities:

$$w^* \equiv \phi_y \cdot y'(b - x^*) \cdot [1 - \phi_a \cdot a(x^*)] = \phi_y \cdot y(b - x^*) \cdot \phi_a \cdot a'(x^*). \tag{8}$$

We can compare the equilibrium price of resources to what it would be in a benchmark economy that does not include rent-seeking activities: $\phi_y \cdot y'(b)$. We refer to this quantity as the "marginal social value of resources", since it captures an alternative benchmark in which all resources are allocated "efficiently" to increase surplus, that is, without any diversion of resources to appropriate economic surplus already created. This benchmark also

[1] If the number of firms competing for the same resources was small, the equilibrium price of resources could be inflated by what Glode and Lowery (2016) call a "defense premium": firm i would be willing to pay a premium to outbid firm j and prevent it from acquiring resources that could be used to steal firm i's surplus. We shut down this strategic bidding behavior from our model, since it is superfluous to our paper's key insights.

captures the standard practice in growth models of abstracting from rent-seeking activities.

If we focus our attention on how the resources allocated to surplus appropriation affect the marginal benefit of investing in surplus creation, we can see two forces going in opposite directions. First, the fact that a fraction $[1 - \phi_a \cdot a(x^*)]$ of the surplus a firm creates is appropriated by a rival firm lowers the marginal value of allocating resources for surplus-creating activities in the first place. Second, the fact that a firm's optimal allocation of resources reduces the quantity of resources invested in surplus-creating activities increases the marginal benefit of investing in these activities, $\phi_y \cdot y'(b - x^*)$, when $y(\cdot)$ is strictly concave. Overall, the existence of rent-seeking opportunities leads resources to be "overpriced" in a symmetric equilibrium whenever:

$$y'(b - x^*) \cdot [1 - \phi_a \cdot a(x^*)] > y'(b). \tag{9}$$

This condition is most likely to be satisfied when $y(\cdot)$ is highly concave and the level of surplus appropriation remains low in equilibrium.

3.3 Firm output

We now analyze how industry-wide technological progress affects firm output. While most technological advancements should improve the productivity of surplus-creating activities, our analysis highlights that the benefits are mitigated by the overinvestment of resources in surplus-appropriating activities.

Consider a technological progress that improves the productivity of each type of activities by $d\phi_y > 0$ and $d\phi_a > 0$, respectively. Then, equilibrium firm output, as measured by $\phi_y \cdot y(b - x^*)$, will increase by:

$$y(b - x^*) \cdot d\phi_y - \phi_y \cdot y'(b - x^*) \cdot \frac{\partial x^*}{\partial \phi_a} \cdot d\phi_a. \tag{10}$$

This increase in firm output is inferior to what it would be under the benchmark allocation without rent seeking, that is, if all resources were allocated to surplus creation: $y(b) \cdot d\phi_y$. The wedge between benchmark and equilibrium output levels is affected by the current productivity parameters ϕ_y and ϕ_a in a non-linear way (remember the expression for $\frac{\partial x^*}{\partial \phi_a}$ derived in equation (7)). In what follows we parameterize the model to provide a numerical illustration in which the allocation of resources towards rent-seeking activities become so relevant that the relationship between productivity measures and equilibrium output appears to be concave, and even negative, in some parametric regions.

4 Parameterized Example

To illustrate the intuition behind our insights, we parameterize the model by setting $a(x) = \frac{x}{1+x}$ and $y(s) = \frac{s}{1+s}$. The first-order condition that characterizes the optimal allocation of resources in a symmetric equilibrium then becomes:

$$\frac{1}{(1+b-x^*)^2} \cdot \left[1 - \phi_a \cdot \frac{x^*}{1+x^*}\right] = \frac{b-x^*}{1+b-x^*} \cdot \phi_a \cdot \frac{1}{(1+x^*)^2}, \tag{11}$$

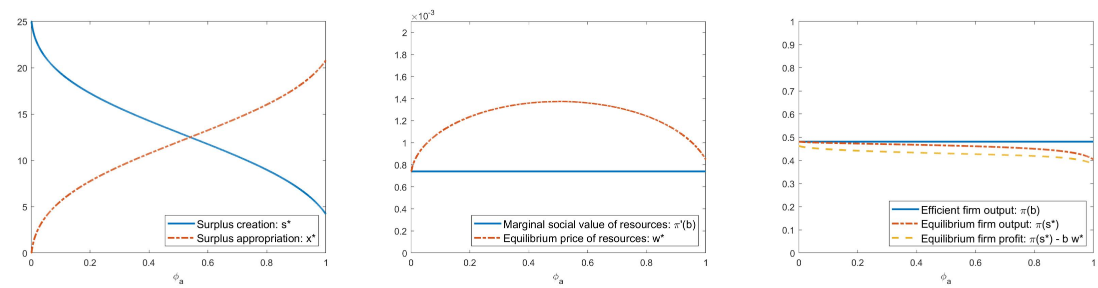
which pins down x^* purely as a function of the abundance of resources b and the productivity of surplus-appropriating activities, ϕ_a, independent of the productivity of surplus-creating activities, ϕ_y. The equilibrium price of resources is:

$$w^* = \phi_y \cdot \frac{1}{(1+b-x^*)^2} \cdot \left[1 - \phi_a \cdot \frac{x^*}{1+x^*}\right] = \phi_y \cdot \frac{b-x^*}{1+b-x^*} \cdot \phi_a \cdot \frac{1}{(1+x^*)^2}, \tag{12}$$

which does depend also on the productivity of surplus-creating activities, ϕ_y.

To illustrate the impact of technological progress on the industry, we start with a simple scenario where technological progress is assumed to only improve the productivity of rent-seeking activities. This simple scenario will help highlight the perverse effect of excessively allocating resources to surplus appropriation in response to industry-wide technological progress. Once we have covered this scenario, we will generalize our analysis by allowing technological progress to affect both productive and rent-seeking activities.

Figure 1 plots, for various levels of ϕ_a, the optimal allocation of resources (Panel (a)), the resulting price of resources (Panel (b)), firm output and profit (Panel (c)) when each firm has access to a supply $b = 25$ of resources and the productivity of surplus-creating activities is fixed at $\phi_y = 0.5$.



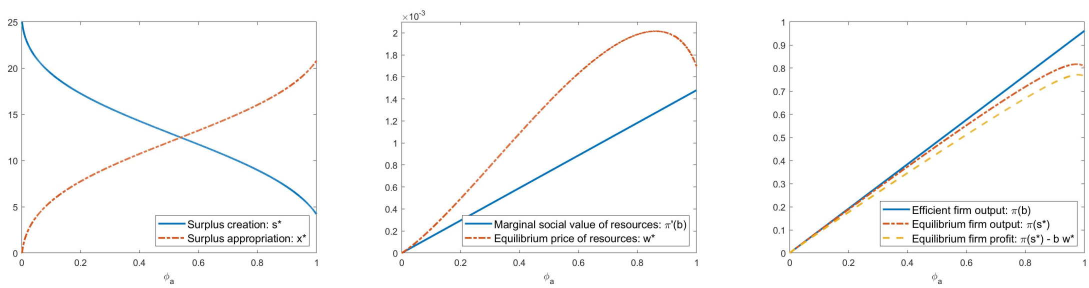
(a) Allocation of resources **(b)** Price of resources **(c)** Firm output/profit

Figure 1

Impact of technological progress in rent-seeking activities only. The graphs illustrate how varying the productivity of surplus-appropriating activities (i.e., ϕ_a), while keeping the productivity of surplus-creating activities constant (i.e., $\phi_y = 0.5$), affects the optimal allocation of resources, the resulting price of resources, firm output and profit when each firm has access to a supply $b = 25$ of resources.

We can see from Panel (a) of Figure 1 that when $\phi_a = 0$ surplus appropriation is effectively shut down. As in our alternative benchmark without rent seeking, all resources are invested in surplus creation (i.e., $x^* = 0$ whereas $s^* = b$). However, as we increase ϕ_a, firms find it optimal to allocate more resources to rent seeking. Due to the concavity of the production functions $y(\cdot)$ and $a(\cdot)$, the split of resources between surplus creation and appropriation that is biased towards rent seeking inflates the price that firms are willing to pay for resources (i.e., w^*) above the marginal social value of these resources (i.e., $\pi'(b)$), as shown in Panel (b). Yet, once ϕ_a gets sufficiently large, firms invest so much resources in surplus appropriation that it lowers how much firms value resources in equilibrium. This explains the inverted-U shape on resource prices, which are maximized when the economy displays an intermediate mix of resources used to create surplus, but also appropriate it. Panel (c) shows that this allocation of resources leads firm output $\pi(s^*)$ to decrease and get further away from the benchmark level of output $\pi(b)$ as we increase ϕ_a. Once we account for the high cost of acquiring these resources in equilibrium, we see that firm profit can also decrease with industry-wide technological progress that solely improves the productivity of surplus-appropriating activities.

We now explore a richer and arguably more interesting scenario in which technological progress is assumed to improve the productivity of both types of activities: surplus creation and appropriation. In particular, Figure 2 plots the equilibrium allocation of resources (Panel (a)), the resulting price of resources (Panel (b)), firm output and profit (Panel (c)) when the productivity levels of surplus creation and surplus appropriation move in parallel, i.e., $\phi_y = \phi_a$, and each firm has access to a supply $b = 25$ of resources.



(a) Allocation of resources **(b)** Price of resources **(c)** Firm output/profit

Figure 2

Impact of equal technological progress in both types of activities. The graphs illustrate how varying the productivity levels of surplus-appropriating activities and surplus-creating activities in parallel (i.e., $\phi_y = \phi_a$) affects the optimal allocation of resources, the resulting price of resources, firm output and profit when each firm has access to a supply $b = 25$ of resources.

Even though ϕ_y and ϕ_a are now assumed to move together and affect in the same extent both creation and appropriation of surplus, Panel (a) shows that firms still find it optimal to allocate more of their resources to surplus appropriation in response to industry-wide technological progress. In fact, Panel (a) of Figure 2 is identical to Panel (a) of Figure 1. As was clear from equation (4), any industry-wide technological progress in surplus creation boosts the rewards to surplus creation for a given firm in the same proportion that it boosts the rewards from appropriating its rival's (now larger) surplus. Thus, the level of ϕ_y does not enter a firm's optimal allocation decision and any industry-wide technological progress to both types of activities directly results in more overinvestment in surplus appropriation. While the marginal social value of resources is increasing with ϕ_y, we see from Panel (b) that the equilibrium price of resources is still inflated to a higher level by the inefficient investment of resources in rent seeking. Moreover, despite the fact that our parameterization features production functions $\pi(\cdot)$ and $\alpha(\cdot)$ that are linear in the productivity parameters $\phi_y = \phi_a$, we can see from Panel (c) of Figure 2 that equilibrium output is concave in these productivity measures (unlike the socially efficient output). This concavity is driven by the firms' response to technological progress that increases the productivity of both types of activities. Firms respond to this progress by allocating a smaller share of their resources to surplus creation.

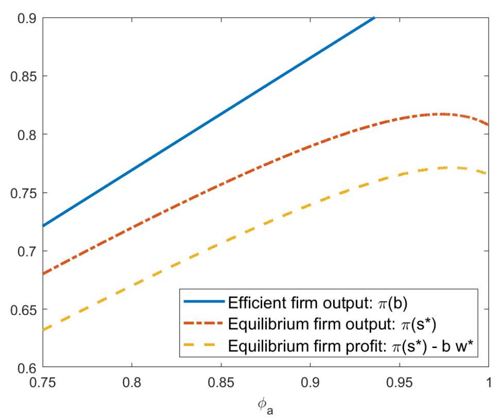
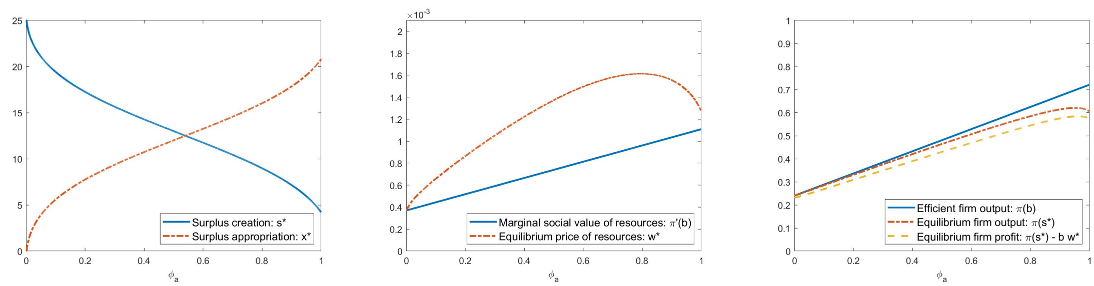


Figure 3
Non-monotonic relationship between firm output/profit and technological progress in both types of activities. The graph illustrates how varying the productivity levels of surplus-appropriating activities and surplus-creating activities in parallel (i.e., $\phi_y = \phi_a$) affects firm output and profit for high productivity levels when each firm has access to a supply $b = 25$ of resources.

We even see in Figure 3, which zooms in on the region where $\phi_a \in [0.75, 1]$, that further technological progress can result in a drop in firm output and profit when the productivity parameter becomes large enough. Thus, the negative impact of firms' misallocation of resources on output and profit can be so severe that it dominates the positive impact of higher productivity due to industry-wide technological progress.

Finally, we consider for the sake of robustness a scenario that can be interpreted as a convex combination of the previous parameterizations: we set $\phi_y = 0.5 + 0.5 \cdot \phi_a$. Figure 4 shows patterns in allocation, price, firm output and profit that are all consistent with the takeaways from Figures 1, 2, and 3.



(a) Allocation of resources **(b)** Price of resources **(c)** Firm output/profit

Figure 4

Impact of unequal technological progress in both types of activities. The graphs illustrate how varying the productivity levels of surplus-appropriating activities and surplus-creating activities at different rates (i.e., $\phi_y = 0.5 + 0.5 \cdot \phi_a$) affects the optimal allocation of resources, the resulting price of resources, firm output and profit when each firm has access to a supply $b = 25$ of resources.

5 Robustness

In this section, we extend our model to investigate the robustness of our key insights to a variety of possibilities, and show that the main insight survives those alternatives.

5.1 Multiple rival firms

For tractability, our baseline analysis assumed that each firm i was appropriating the surplus of one rival firm (i.e., firm j) and vice-versa. However, all our insights survive in an environment where firms have several rivals competing for their surplus. If firm i had N rivals, we could write its payoff as:

$$\pi_i(s_i) \cdot \left[1 - \sum_{j=1}^{N} \alpha_j(x_j)\right] + \sum_{j=1}^{N} \pi_j(s_j) \cdot \alpha_i(x_i). \tag{13}$$

With industry-wide technological parameters, firm i's first-order condition would become:

$$y'(s_i) \cdot \left[1 - \phi_a \cdot \sum_{j=1}^{N} a(x_j)\right] = \sum_{j=1}^{N} y(s_j) \cdot \phi_a \cdot a'(x_i). \tag{14}$$

A firm's optimal allocation of resources would behave similarly, from a qualitative standpoint, when $N > 1$ as it does in our baseline model (where $N = 1$). In particular, the productivity of surplus creation ϕ_y does not enter the first-order condition, which implies that technological progress would tilt the allocation of resources towards rent seeking whenever such progress increases ϕ_a.

5.2 Relative investment in surplus appropriation

In our baseline analysis, we assumed that firm i could invest resources to appropriate firm j's surplus whereas firm j could invest resources to appropriate firm i's surplus. In some contexts, however, firm i's investments in surplus-appropriating activities are also associated with the added benefit of reducing rival firms' ability to appropriate firm i's surplus. For example, a technology firm can build a legal department that allows to find loopholes in rival firms' patents *as well as* sue rival firms that infringe the firm's own patents (evidence of these practices has been recently provided by Argente et al. (2020). In such instances, firm i's ability to appropriate firm j's surplus could be modeled as a function of firm i's investment in surplus-appropriating activities *relative* to that of firm j. Formally, we could write each firm's first-order condition as:

$$\phi_y \cdot y(s_i) \cdot [1 - \phi_a \cdot a(x_j - x_i)] + \phi_y \cdot y(s_j) \cdot \phi_a \cdot a(x_i - x_j). \tag{15}$$

And with industry-wide productivity parameters, the first-order condition becomes:

$$y'(s_i) \cdot [1 - \phi_a \cdot a(x_j - x_i)] = \phi_a [y(s_i) \cdot a'(x_j - x_i) + y(s_j) \cdot a'(x_i - x_j)]. \tag{16}$$

As in the baseline model, the productivity of surplus-creating activities still drops out of the first-order condition. Moreover, in a symmetric equilibrium, the first-order condition can be written as:

$$y'(b - x^*) \cdot [1 - \phi_a \cdot a(0)] - 2\phi_a \cdot y(b - x^*) \cdot a'(0) = 0. \tag{17}$$

By applying the implicit function theorem, we get:

$$\frac{\partial x^*}{\partial \phi_a} = \frac{y'(b - x^*) \cdot a(0) + 2y(b - x^*) \cdot a'(0)}{-y''(b - x^*) \cdot [1 - \phi_a \cdot a(0)] + 2\phi_a \cdot y'(b - x^*) \cdot a'(0)} > 0. \tag{18}$$

As in the baseline model, a technological progress that increases ϕ_a leads firms' to tilt their allocation of resources towards surplus appropriation (regardless of what happens to ϕ_y). As a result, the main insights we derive in the baseline analysis are expected survive when the *relative* investment in rent seeking is what drives $\alpha(\cdot)$, the fraction of its rivals' surplus that each firm can appropriate.

5.3 Factor-augmenting technological changes

In our baseline analysis, we have focused on a technological change improving total factor productivity (TFP), as surplus- creating and appropriating activities display production functions of the form $\phi_y \cdot y(s)$ and $\phi_a \cdot a(x)$, respectively. In such environment, we have shown that the allocation of resources between the two activities only depends on ϕ_a. In this extension, we show that this result also holds when considering a factor-augmenting technological change, at least for the family of standard Cobb-Douglas production functions.

To see this equivalence, the "Cobb-Douglas version" of the TFP-augmenting technological change analyzed in the baseline model yields the following specifications: $\pi(s) = \phi_y \cdot y(s) = \phi_y \cdot s^\eta$ for surplus-creating activities and $\alpha(x) = \phi_a \cdot a(x) = \phi_a \cdot x^\gamma$ for surplus-appropriating activities. Then, with a budget constraint that is binding (i.e., $s = b - x$), we get the following expressions:

$$\pi'(b-x) = \phi_y \cdot y'(s) = \eta \frac{\pi(b-x)}{b-x} \qquad \text{and} \qquad \alpha'(x) = \phi_a \cdot a'(x) = \gamma \frac{\alpha(x)}{x} \tag{19}$$

The first-order condition in a symmetric equilibrium can then be rewritten as:

$$\eta \frac{\pi(b-x^*)}{b-x^*} [1-\alpha(x^*)] = \pi(b-x^*)\gamma \frac{\alpha(x^*)}{x^*} \qquad \Longrightarrow \qquad \frac{\alpha(x^*)}{1-\alpha(x^*)} = \frac{\eta x^*}{\gamma(b-x^*)}, \tag{20}$$

which replicates, for the case of Cobb-Douglas production functions, our previous result that allocation of resources only depends on the productivity level of surplus-appropriating activities.

Now, let's consider an alternative specification that allows for factor-augmenting technological changes: $\pi(s) = y(\phi_y \cdot s) = (\phi_y \cdot s)^\eta$ for surplus-creating activities and $\alpha(x) = a(\phi_a \cdot x) = (\phi_a \cdot x)^\gamma$ for surplus-appropriating activities. Notice that in this case, the technological change does not increase the whole production, but it operates through a direct increase of the factor of production. Still, taking derivatives yields the same expressions as in (19), and then the first-order condition is also given by (20).

6 Conclusion

When technology is used to facilitate both productive and rent-seeking activities, albeit to different extents, industry-wide technological advancements such as big data, machine learning, and artificial intelligence create a disproportionate reallocation of resources towards rent seeking. Over time, the economy evolves towards a rent-seeking economy in response to technological progress. This long-run reallocation of resources towards rent seeking has important implications for the relative price of resources that can serve as inputs for rent-seeking activities and for the benefits of technological breakthroughs on economic activity.

References

Argente, David, Salome Baslandze, Douglas Hanley and Sara Moreira, 2020, "Patents to Products: Product Innovation and Firm Dynamics," *Working Paper, Penn State University*

Barro, Robert J., 1999, "Notes on Growth Accounting," *Journal of Economic Growth* 4, 119-137.

Baumol, William J., 1990, "Entrepreneurship: Productive, Unproductive, and Destructive," *Journal of Political Economy* 98, 893-921.

Célérier, Claire, and Boris Vallée, 2019, "Returns to Talent and the Finance Wage Premium," *Review of Financial Studies* 32, 4005-4040.

Fishman, Michael J., and Jonathan A. Parker, 2015, "Valuation, Adverse Selection, and Market Collapses," *Review of Financial Studies* 28, 2575-2607.

Gelb, Alan H., John B. Knight, and Richard H. Sabot, 1991, "Public Sector Employment, Rent Seeking and Economic Growth," *The Economic Journal* 101, 1186-1199.

Glode, Vincent, Richard C. Green, and Richard Lowery, 2012, "Financial Expertise as an Arms Race," *Journal of Finance* 67, 1723-1759.

Glode, Vincent, and Richard Lowery, 2016, "Compensating Financial Experts," *Journal of Finance* 71, 2781-2808.

Murphy, Kevin M., Andrei Schleifer, and Robert W. Vishny, 1991, "The Allocation of Talent: Implications for Growth," *Quarterly Journal of Economics* 106, 503-530.

Murphy, Kevin M., Andrei Schleifer, and Robert W. Vishny, 1993, "Why Is Rent-Seeking So Costly to Growth?," *American Economic Review* 83, 409-414.

Philippon, Thomas, 2010, "Engineers vs. Financiers: Should the Financial Sector be Taxed or Subsidized," *American Economic Journal: Macroeconomics* 2, 158-182.

Philippon, Thomas, and Ariell Reshef, 2012, "Wages and Human Capital in the U.S. Financial Industry: 1909-2006," *Quarterly Journal of Economics* 127, 1551-1609.

Rosen, Sherwin, 1981, "The Economics of Superstars," *American Economic Review* 71, 845-858.

Solow, Robert, 1957, "Technical Change and the Aggregate Production Function," *The Review of Economics and Statistics* 39, 312-320.