The macroeconomic impact of firms’ defensive behavior

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Abstract

This paper studies the firm-level and the macroeconomic implications of firms’ defensive behavior, defined as non-productivity improving practices that preserve the company’s competitive advantage. To this aim, I develop a general-equilibrium model of technology adoption with heterogeneous firms and sectors with the following features. First, each sector is populated with a finite number of leaders and followers who compete strategically both in the production and innovation activities. Second, I allow for technology spillovers so that followers can catch-up with leaders but leaders can also influence the extent of technology spillovers by conducting defensive practices. Third, the model embodies two types of entry of firms in that a new firm can either enter the incumbent sectors as a follower or create a technology to produce a new variety as a leader in each sector.

On one hand, the presence of defensive behavior leads more market concentration with a few firms exercising market power, which decreases aggregate productivity because leaders are less incentivized to innovate due to the lack of competition. On the other hand, defensive behavior allows leaders to appropriate a larger share of profits from innovation. This incentivizes more entrants to create new products and become a leader in their respective sector, which improves the production specialization in the economy and thus increases aggregate productivity. My quantitative exploration reveals that the latter effect dominates the former effect in the model that is calibrated for the 2015 U.S. economy, as compared to the model that is calibrated for the 1980 U.S. economy where the relative strength is reversed. Key is product substitutability. In fact, a decline in product substitutability from 1980 to 2015 is necessary for my model to be consistent with the markup distribution that has been fattening in its upper tail over the past decades, and my study suggests a likely link between the rise of superstar firms and their defensive behaviours and the fall in product substitutability.

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1 Introduction

“Success doesn’t necessarily come from breakthrough innovation but from flawless execution. ... the win comes from basic blocking and tackling.” Jain Naveen\(^1\)

Market concentration has been increasingly becoming a common feature across developed economies, with a small number of superstar firms taking up a substantial market share and charging high markups\(^2\). This has caused policy-makers to question the potentially anti-competitive nature of such superstar firms’ dominance, scrutinizing their defensive behaviour of controlling their sectors in ways that are difficult for competitors and potential entrants to compete against\(^3\). Should we impose restrictions on firms’ ability to control their dominant position? I argue otherwise in this paper\(^4\). I develop a quantitative model of oligopolistic competition with technology adoption and show that cracking down on defensive behaviour is not productivity enhancing, when the model is calibrated to the 2015 U.S. economy that is characterized by the skewed markup distribution. When the model is calibrated to the 1980 U.S. economy, in contrast, aggregate productivity increases by cracking down on defensive behavior of firms, with the markup distribution being less skewed. I found that product substitutability plays a crucial role in yielding this ambiguity, together its ability to reproduce the empirically consistent markup distributions at two different time points.

Imposing restrictions on firms’ ability to control their dominant position improves the technology adoption and knowledge spillover, allowing more laggard firms to catch-up and compete against frontier firms. This creates more sectors that are characterized by a neck-to-neck at the technological frontier, incentivizing them to innovate to escape competition. On the other hand, more competition implies that firms’ ability to appropriate the profits generated by innovation is limited, which in turn discourages firms to develop new products. The major contribution of this paper is to quantify the relative magnitudes of each channel; the escape-competition effect and the Schumpeterian effect. The Schumpeterian effect dominates the escape-competition effect in a model that is calibrated to the 2015 U.S. economy, as compared to a model that is calibrated to the 1980 U.S. economy, where the Schumpeterian effect is not quantitatively important and thus welfare and aggregate productivity increase by cracking down on defensive behavior of firms.

My model has the following features distinct in the literature. Firstly, each sector is populated with a finite number of leaders and followers who strategically compete both statically in the production (\(\dot{a}\)

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\(^1\) Jain Naveen, 10 Secrets of Becoming a Successful Entrepreneur, INC. (August 13, 2012).

\(^2\) See, for example, De Loecker et al. (2020), Autor et al. (2020), for seminal works.


\(^4\) See the statement of Senator Elizabeth Warren, in March 2019 for her argument advocating to break up the big tech companies and the article of Feiner, Lauren. “Lina Khan’s FTC takes a first step toward expanding antitrust enforcement.” CNBC, 10 August 2021.
la Cournot) and dynamically in the innovation activities, playing contests in the spirit of Loury (1979). Secondly, the model features two types of entry of firms. A new firm can either enter the incumbent sectors as a follower or create a new technology to produce a new variety as a leader in the sector. Thirdly, leaders’ innovation generates technology spillovers towards followers to catch-up and entrants by improving their potential available technology. Finally, leaders not only can invest in R&D to improve their productivity but also can spend resources to slow down the catch-up of the followers, refereed as defensive practices. For leaders, productivity improving R&D and defensive practices pair with complementarity. In the model, the aggregate output and productivity of the economy reflect the static efficiency, markups, and the dynamic efficiency driven by the technology adoption and the production specialization.

The model is calibrated to match the distribution of markups of the 2015 U.S. economy, as well as the share of defensive expenditure using the percentage of patents citing patents already existing in the firms as proxy. The defensive behavior increases the endogenous TFP and aggregate output by, respectively, 24.5% and 17.7%. The economy with defensive behavior is characterized by a higher R&D intensity, market concentration, production specialization, dispersion of the firms’ size and the markups’ distributions. In the economy with defensive behavior, incumbent firms adopt less productive technologies and the higher productivity improving R&D intensity of firms does not reflect a higher innovation intensity, but it reflects the shift in the distribution of sectors toward those regions in which firms’ productivity is low, and firms’ intensity is high. The fact that firms adopt less productive technologies with defensive behavior does not only depend on the lower productivity of the technologies of followers but it also reflects the adoption of less productive technologies of the leaders. Although leaders adopt less productive technologies, the defensive behavior increases the output share of the 5% largest firms. Given the possibility to produce defensive practices, to further enlarge their market shares and sizes, leaders, currently enjoying large market shares, find optimal to prevent followers from catching up until the depreciation of the technology forces the followers to leave the sectors. The rise in output share of large firms operating in concentrated sectors soars the value weighted markup, while the average markup is mildly affected. The percentage deviations of the distributions of firms’ size and log revenue per worker are, respectively, 27% and 5% higher. This feature reflects also the lower sector average leaders’ turnover within five period that is driven by the higher persistence of the largest 5.0% percent of leaders. Under this framework, the overall effect of the firms’ defensive behavior crucially depends on the elasticity of the aggregate output with respect to the production specialization. While the defensive behavior worsens the technology adoption in the incumbent sectors, due to the weaker escape from competition effect, and it raises the static inefficiency of the economy, it incentivizes the R&D of the potential entrepreneurs that develop new technologies to produce new products given higher appropriability.
Furthermore, the model shows that the growth of the gap between value-weighted and average markups, experienced by the U.S. economy in the last decades, can reflect the rise of the gain deriving from the production specialization and explain the pervasiveness of firms’ defensive practices. I increased the parameter’s value that governs substitution elasticity between sectors and, in turn, the monopolistic markups, to match the value-weighted markups of the U.S. in 1980. Comparing the two calibrated economies, I found the rise of the monopolistic markups can represent the structural change experienced by the U.S. economy that jointly explains the rises in the markets concentration, R&D intensity and the pervasiveness of the firms’ defensive practices. The rise of the monopolistic markups increases the incentive of the leaders to maintain their relative advantage toward the direct competitors within sectors, and consequently, it spurs the production of defensive practices. Moreover the presence of firms’ defensive behavior amplifies the effects of the rise of monopolistic markups on market concentration and dispersion of markups and firms’ size distributions. Conversely, in the economy with low monopolistic markups the defensive behavior reduces aggregate output and endogenous productivity. The lower monopolistic markups reflects the weaker effect that the production specialization has on the productivity of the factors and consequently on the aggregate output and productivity. Although less varieties of sectors exist in the economy, the fall of sectors’ concentration and the adoption of more productive technologies, due to the absence of defensive practices, increases the output and endogenous productivity. This exercise shows that the monopolistic rent can represent the structural change experienced by the U.S. economy that jointly explains the rises in the markets concentration, R&D intensity and pervasiveness of the defensive behavior as well as the fall in business dynamism.

Finally I compare the macroeconomic effects of the rise of product substitutability within sectors with the effects of fall of the substitutability between sectors. The objective is to test whether the Superstar firms’ Theory of [Autor et al.] (2020), in which the rise of competition increases concentration by shrinking and exiting the low productive firms, affects the economy similarly to the reduction in substitutability between sectors. The rise of competition within sector, such as the the reduction of the substitutability between sectors, can justify the both rises of R&D intensity and the output share of the most productive firms in the sectors. However, the rise of substitutability within sector can not explain the dynamic of the defensive behavior and markups. This exercise confirms that the growth of the production of firms’ defensive practices, such as the rise in markets concentration, may reflect the rise of the monopolistic rents and, consequently, the rise of the gain from the production specialization.

Related literature The theoretical ambiguity of the macroeconomic effect of firms’ defensive behavior is associated with the non-monotonic relationship between product market competition and innovation as shown in [Aghion et al.] (2005). The concept retraces to [Schumpeter] (1976) that argued that the innova-
tion activities are driven by the expectation of monopolistic rents, and consequently, high competition may weaken the incentive to innovate. Hence, defensive behavior may promote innovation by spurring the introduction of more productive technologies in the incumbent sector or the development of new technologies to produce new goods, because it reduces the knowledge spillovers and increases the innovator’s ability to appropriate the profits generated by the innovation. On the other hand, Arrow (1962) argued that monopolists lack incentive to innovate because they already enjoy supernormal profits. My model reproduces the inverted-U relationship between the sector’s expected R&D intensity and the competition level approximated with the Herfindahl index, mimicking the evidence found in the data in Aghion et al. (2005). This quadratic relationship is built on the different correlations between the market share and concentration that leaders and followers have. Both leaders and followers show that firm’s productivity improving R&D intensity is negatively correlated with market share, supporting the studies of Akcigit and Kerr (2018) and Akcigit (2009), but leaders’ market share is positively correlated with the concentration. Indeed, in high concentrated sectors, leaders do not implement productivity improving R&D because the technology spillovers are high, and they massively produce defensive practices to maintain their competitive advantage.

This paper is inspired by the idea that firms compete concurrently in the product market, innovation activities, and production practices to defend their position that retraces to Stigler (1971) that argued that regulation is acquired by the industry and is designed and operated primarily for its benefit. Later, this concept was formalized by Krusell and Rios-Rull (1996) that developed a model of long cycle of stagnation and growth. Over the cycle, incumbent producers use their political power to prevent new technologies from being adopted until the incumbents are phase out of the economy. Following this, Comin and Hobijn (2009) empirically showed how lobbying activities affect legislative authorities to erect entry barriers that significantly slow the speed of diffusion of new technology and protect the incumbents. More recently, Zingales (2017) presented a political theory of firm, based on the concept of Medici vicious circle in which market power is used to obtain political power inducing to additional market power. Gutiérrez and Philippon (2019) detected that the regulation driven by lobbying induces a fall in entry elasticity regarding Tobin’s Q and in the growth of small firms relative to large ones in the U.S. Akcigit et al. (2018) empirically studied how political connections affect innovation activities and firm dynamics.

Moreover, the macroeconomic studies have been investigating another tool used by firms to defend their market position: the implementation of defensive and strategic patents to prevent rivals from leapfrogging the market leaders. Shapiro (2000) first considered this trend and described the patent thickets as a dense

As in Acemoglu and Akcigit (2011), the trickle-down incentive is indispensable for designing intellectual policy right (IPR) system: Greater protection to firms that have a greater leads improves the incentives of innovation both to technologically advanced firms and to firms with limited leads because of the prospect of reaching levels with higher technology protection.

web of overlapping intellectual property rights that a company must overcome to actually commercialize new technology\footnote{For example, a famous patent thicket of the car industry is the one built by Toyota around its hybrid technology \cite{Murphy,John. “Toyota Builds Thicket of Patents Around Hybrid To Block Competitors.” The Wall Street Journal. 10 August 2021.}.\cite{Abrams et al. 2013} empirically estimated an inverted-U relationship between citations and value of patents arguing that high value innovations create a greater incentive to protect them, which deters downstream innovation and induces to a negative relationship between citations and value above a threshold. Consistent with the previous study, \cite{Argente et al. 2020} empirically showed that market leaders are more patent intensive, but those patents are associated with declining product introduction of the competitors, supporting the notion that market leaders use their patents to limit competition. Compared to those papers, the proposed model provides a general equilibrium framework that allows to extensively identify and study how a wider concept of defensive behavior of firms can affect the firms’ dynamic, consequently, the economy. First to clearly disentangle the trade-off between promoting leaders or followers’ innovation, the model is characterized by the complementarity between leaders’ productivity improving R&D investment and defensive practices. Second, leaders’ innovation generates knowledge spillovers toward followers and entrants. Third, the sector heterogeneity assists in revealing how the production of defensive practices is influenced by the sector structure helping the design potential policy interventions. Also, the sector heterogeneity is fundamental to explain the effects of defensive behavior on the dispersion of firms’ size and markups distributions. Fourth, endogenous creation of sectors aids in determining the conditions under which the defensive behavior increases the aggregate output.

This study is also related to the broader literature on the decline in business dynamism, increasing difference between firms and market concentration. \cite{Cavenaile et al. 2020} showed the decline in productivity growth is largely driven by the increasing costs of innovation. \cite{Akcigit and Ates 2019} argued that the reduction business dynamism is due to the declining knowledge diffusion from market leaders to followers due to the implementation of a defensive behavior that would prevent rivals from leapfrogging the market leaders. Based on a cross-country comparison, \cite{Andrews et al. 2015} provided evidence of the slow down of the technology diffusion between firms on the global and national frontiers probably caused by the nature of new technologies and the increasing importance of the use of data and tacit knowledge in production processes. \cite{Grullon et al. 2019} stated that the rise in concentration can be partly explained by the weak anti–trust law enforcement toward large firms. \cite{Autor et al. 2020} argued that the rise of concentration supports the Winner takes all hypothesis where the most productive firms increase their market shares due to higher competition driven by globalization. This study introduces an endogenous mechanism to reveal the structural change may have raised the pervasiveness of defensive behavior and the resultant rise in dis-
persion of firms’ size distribution. The model shows that reducing substitutability between sectors increases the incentive of the leaders to implement defensive practices to protect their relative advantage toward the direct competitors within sectors.

This paper is also inspired by the empirical literature on the recent trend of the market power as De Loecker and Warzynski (2012), De Loecker et al. (2016), De Loecker and Eeckhout (2018), Bank (2018), Van Reenen (2018) and Calligaris et al. (2018). Focusing on the U.S. economy, seminal papers on the rising market power are Grullon et al. (2019), De Loecker et al. (2020), Autor et al. (2020) and Baqeef and Farhi (2020). My contribution is to show how the defensive behavior strongly amplifies the effects of the reduction of product substitutability on the dispersion of the markups distribution.

This paper contributes to the literature that examines the macroeconomic implications of product differentiation such as Chamberlin (1950), Lancaster et al. (1974), Dixit and Stiglitz (1977), Krugman (1980), Ethier (1982) and Dhingra and Morrow (2019). The paper differs as it introduces the strategic interactions in the production and the innovation activities that bring out a trade-off between technology adoption and production differentiation.

Finally this study is also inspired by the literature that studies the dynamics of competitive industries such as Jovanovic and MacDonald (1994a), Jovanovic and MacDonald (1994b), Eeckhout and Jovanovic (2002) and Klepper (2015), and it introduces the strategic interaction and the defensive behavior. In addition, the model is consistent with the empirical evidences provided by Bloom et al. (2013) that showed that the technology spillovers are increasing in firms’ size.

The remainder of this study is organized as follows: Sections 2 and 4 present the theoretical framework and the calibrated theoretical model, respectively; Sections 5 and 6 examine equilibrium and steady state, respectively; Section 7 I examine how the distribution of markups reveals the firm-level and the macroeconomic implication of firms defensive behavior; finally, Section 8 concludes the study.

2 Theoretical Framework

Time is discrete in infinite horizon. There are a large number of heterogeneous sectors. Each sector is populated by an endogenous finite number of oligopolistic firms, leaders and followers, that compete à la Cournot.

Each period comprises a morning and an afternoon session where oligopolistic firms invest in R&D to improve their idiosyncratic productivities. Moreover firms can also spend resources in defensive practices to prevent competitors from innovating. Finally, potential entrepreneurs can invest resources in R&D to create a new technology that is orthogonal to the existing ones, and it generates a new sector.
The model timing can be summarized as follows:

- **Early morning**: Creation of new sectors by potential entrepreneurs and entry of firms in the incumbents sectors.
- **Late morning**: followers invest in R&D to catch up the leaders; meanwhile, leaders implement defensive practices to prevent it.
- **Early afternoon**: Production.
- **Late afternoon**: Leaders invest in R&D to improve their productivities.

The model economy is presented as follows.

## 2.1 Production

### 2.1.1 Final Good and Sector Output

**Final Output.** The final good, $Y$, is produced by a competitive firm using the output of a continuum of sectors $y_j$ for $j \in [0, M]$ as inputs subject to a CES production function:

$$Y = \left( \int_0^M y_j^{\frac{\eta-1}{\rho}} \, dj \right)^{\frac{\rho}{\eta-1}}, \quad (1)$$

where $\eta > 1$ is the elasticity of substitution between sectors.

**Sector Output** Each sector is populated by an endogenous finite number of oligopolistic firms $N_j$. Oligopolistic firms compete à la Cournot by choosing the quantities to produce facing an elastic demand curve.

Similarly, the sector output, $y_j$, is produced by a competitive firm that use the output produced by the firms in the sectors subject to a CES production function:

$$y_j = \left( \sum_{i=1}^{N_j} \frac{y_{i,j}^{\frac{\rho-1}{\rho}}}{y_{i,j}^{\nu}} \right)^{\frac{\rho}{\rho-1}} \quad (2)$$

where $y_{i,j}$ is the output produced by the oligopolistic firm $i$ in sector $j$. $\rho > \eta$ is the elasticity of substitution between the firms in the sector.

**Production in the Sectors.** In the early afternoon, production takes place. In each sector $j$, two oligopolistic firms exist: leaders, the most productive firms, and followers. Firms rent capital stock, $k$, and
hire labor, \( l \). Firms produce using a constant-returns-to-scale Cobb-Douglas production function:

\[
y_{i,j} = \begin{cases} 
\varepsilon_{i,j}^l \alpha_{i,j}^{1-\alpha}, & \text{if } i \text{ is a leader} \\
\varepsilon_{i,j}^f \alpha_{i,j}^{1-\alpha}, & \text{if } i \text{ is a follower,}
\end{cases}
\]  

(3)

where \( \varepsilon_{i,j} \in \{\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_{N+}\} \), \( \varepsilon^l > \varepsilon^f \) is the relative productivity. So each sector \( j \) is defined by:

\[
(\varepsilon_j^l, \varepsilon_j^f, n_j^l, n_j^f)
\]

where \( n^l \) and \( n^f \) are the number of leaders and followers.

2.2 R&D and innovation

Each period comprises by a morning and an afternoon session where the oligopolistic firms invest in R&D to improve their relative productivity. The technology frontier of the economy deterministically grows at the rate \( \bar{\varepsilon} \). The firm that fails to adopt new technologies will experience a decline in relative productivity.

**Morning.** \( n_j^f \) followers play an innovation race by employing \( x_{i,j}^f \) units of R&D subject to the cost function \( C(x_{i,j}^f) \). Winning the contest allows the follower to become an additional leader. Meanwhile, \( n_j^l \) leaders implement defensive practices to prevent it. In particular, leaders play a public good game by choosing \( x_{i,j,1}^l \) units of defensive practices to reduce the probability of success of the followers subject to the cost \( C(x_{i,j,1}^l) \).

The contest probability that a follower moves up to the sector frontier in sector \( j \) is:

\[
p_{j,fs}(X_{j,1}^l, X_j^f) = \frac{R^l}{X_{j,1}^l + R^l} \times \frac{X_j^f}{X_j^f + R^f}
\]

(4)

with \( X_{j,1}^l = \sum_{i=1}^{n_j^l} x_{i,j,1}^l \), \( X_j^f = \sum_{i=1}^{n_j^f} x_{i,j}^f \), \( R^f \) and \( R^l \) constant. Consequently, I can define the contest probability that the follower \( i \) employing \( x_{i,j}^f \) units of R&D wins as:

\[
p_{i,j,fs}(x_{i,j}^f, X_{j,1}^l, X_j^f) = p_{j,fs}(X_{j,1}^l, X_j^f) \times \frac{x_{i,j}^f}{X_j^f}
\]

(5)

and I can finally define the contest probability that a follower \( \neq i \) succeeds as:

\[
p_{i,j,fs}(x_{i,j}^f, X_{j,1}^l, X_j^f) = p_{j,fs}(X_{j,1}^l, X_j^f) \times \frac{X_j^f - x_{i,j}^f}{X_j^f}
\]

(6)
Given a generic sector $j$ whose $n_l^j$ leaders’ relative productivity is $\varepsilon_h$ and $n_f^j$ followers’ relative productivity is $\varepsilon_h - s$ with $s \geq 1$, I can describe the endogenous transition probability from morning to afternoon as follows:

$$(\varepsilon_l', \varepsilon_l', n_l^l, n_f^f) =$$

$$\begin{cases} (\varepsilon_{h,j}, \varepsilon_{h-s,j}, n_l^l + 1, n_f^f - 1) & \text{with probability } p_{fs} \\ (\varepsilon_{h,j}, \varepsilon_{h-s,j}, n_l^l, n_f^f) & \text{with probability } 1 - p_{fs} \end{cases}$$

(7)

When followers’ relative productivity of the sector is below $\varepsilon_1$, the new entrants can enter the sectors by paying an entry cost $c_e$, and to produce, they must win the contest and become additional leaders. The unsuccessful entrants are forced to leave the sectors.

In the case of a generic sector $j$, whose $n_l^j$ leaders’ relative productivity is $\varepsilon_h$ and $n_f^j$ followers’ relative productivity is $\varepsilon_h - s$ with $s = h$, I can describe the endogenous transition probability from morning to afternoon as follows:

$$(\varepsilon_l', \varepsilon_l', n_l^l, n_f^f) =$$

$$\begin{cases} (\varepsilon_{h,j}, \varepsilon_{0,j}, n_l^l + 1, 0) & \text{with probability } p_{fs} \\ (\varepsilon_{h,j}, \varepsilon_{0,j}, n_l^l, 0) & \text{with probability } 1 - p_{fs} \end{cases}$$

(8)

**Afternoon.** After the production takes place, leaders can play another race by employing $x_{l,i,j,2}$ units of R&D subject to the cost $C(x_{l,i,j,2})$ to implement an innovation that improves the firm’s productivity. The winner leader draws the new productivity level from a uniform, $U \sim \{\varepsilon', \varepsilon_N\}$, and having observed it, decides whether or not to implement it. The implementation allows the winner leader to become the only leader in the sector the next period, to convert the other leaders into followers, and to force the current followers out of the sector. The winner leader can decide not to implement the new technology to avoid to generate positive technology spillovers that can shrink the technology gap with followers. So the leader will implement the innovation if the associated productivity exceeds a certain threshold $\varepsilon^*$. Similarly, I define the probability that a leader wins the contest in sector $j$ as:

$$p_{ls}(X_l^1) = \frac{X_l^1}{X_l^2 + R^2},$$

(9)

with $X_l^2 = \sum_{i=1}^{n_l^l} x_{i,j,2}^l$ and $R_2$ constant. The probability of success for the leader $i$:

$$p_{ls}(x_{i,j,2}, X_l^1) = p_{ls}(X_l^1) \frac{x_{i,j,2}^l}{X_l^1},$$

(10)
Finally, the probability of success for the leader $\neq i$:

$$p_{ls}(x_{1,j,2}^l, X_{j,2}^l) = p_{ls}(X_{j,2}^l) \frac{X_{j,2}^l - x_{i,j,2}^l}{X_{j,2}^l}.$$  

(11)

So, considering a generic sector $j$ whose $n_l^j$ leaders’ relative productivity is $\varepsilon_{h,j}$ and $n_f^j$ followers’ relative productivity is $\varepsilon_{h-s}$ with $s \geq 1$ and $h - s \geq 1$, I can describe the endogenous transition probability of the sector from afternoon to early morning as follows:

$$\begin{align*}
(\varepsilon_j', \varepsilon_j, n_j^l, n_j^f) &= \begin{cases} 
(\varepsilon_{g,j}, \varepsilon_{h-1,j}, \varepsilon_{h-s-1,j}, 1(n_j^l), n_j^f + n_j^l - 1(n_j^l)), & \text{with prob. } p_{ls}(\varepsilon_g \geq \varepsilon_j') \\
(\varepsilon_{h-1,j}, \varepsilon_{h-s-1,j}, n_j^l, n_j^f + n_j^l), & \text{with prob. } 1 - p_{ls} + p_{ls}(\varepsilon_g < \varepsilon_j')
\end{cases}
\end{align*}$$

where $\varepsilon_g \in \{\varepsilon_{h,j}, \ldots, \varepsilon_{N^e}\}$.

(12)

2.2.1 Entry and Exit

**Incumbent Sectors.** In each period, firms leave the economy for three different reasons in the late afternoon. First, firms exit the sector when their productivity declines below the minimum productivity level in the economy $\varepsilon_1$. Second, followers are forced to leave the sector when one leader succeeds in innovating. Third, each sector faces an exogenous probability of destruction $\phi$ that forces all those firms to leave the economy.

Regarding the entry in the incumbent sectors, in the early morning, $n_j^e$ new firms can enter the sectors as followers by paying an entry cost $c_e$ once the available followers’ technology allows them to immediately produce. In the other way around entrants, after paying the entry cost, must succeed in the process of imitation of the leader’s technology before to start to produce.

**New Sectors.** Before the entry takes place, there is a mass $\Sigma$ of potential entrepreneurs that invest $x^e$ units of R&D subject to the cost function $C(x^e)$. In case the potential entrepreneur succeeds, she creates a new technology with the associated productivity drawn from a uniform distribution $\mathcal{U} \sim \{\varepsilon_1, \ldots, \varepsilon_{N^e}\}$ that generates a new sector. These new technologies are orthogonal to the existing ones and they reflect the Romer (1990)’s idea that innovation comes from creating new technology to produce new good as stated in Jones (2019).
Similarly, I can define the probability of succeed as:

\[ p_e(x_e) = \frac{x_e}{x_e + R_e}, \]  

(13)

where \( R_e \) is constant.

I assume that creating these new technologies allows entrants to enter this new sector with a technology whose productivity is close to that generated by the successful potential entrepreneur. For example, if the successful entrepreneur draws \( \epsilon_g \) productivity, then the entrants can enter the sector as followers with a productivity \( \epsilon_{g-1} \). This modeling choice mimics the fact that, in new industries, new products attract new producers trying to imitate it in the early stage of a new industry as, shown in Jovanovic and MacDonald (1994b).

Figure 1 shows the potential evolution of a sector defined as \( (\epsilon_l, \epsilon_f, n_l, n_f) \), considering the two contests played in the morning and afternoon. Indeed, in the late morning, followers attempt to discover a new way of performing the same task as the leading-edge technology, while leaders try to prevent it. The sector structure changes in case a follower succeeds with \( p_{fs} \) probability having an additional leader in the afternoon. After the production takes place, leaders play the race among them. A leader wins with \( p_{ls} \) probability and decides whether or not to implement the new technology. Regarding implementation, the leader will be the only leader of the sector in the following period, and the looser leaders will be the followers. Current followers will have to leave the sector and new entrants \( n_e' \) will enter as additional followers. In the the other way around, or in case no leader succeeds, the sector structure will not change except for the technology depreciation that will affect firms’ productivity and the entrance of new additional firms. However, in case of no implementation of innovations, the sector structure will not change, except for the technology depreciation that will affect firms’ productivity.
3 Equilibrium

3.1 Household

There is a representative household in the economy. Each period the household chooses consumption, $C$, investment into physical capital $I$, and the supply of labour on a competitive factor market $L$ to maximize its lifetime expected utility subject to the budget constraints:

$$C + I = Lw + RK + \Pi,$$

$$K' = K(1 - \delta) + I. \tag{14}$$

where $\delta$ is depreciation rate of the physical capital, $w$ is the competitive wage rate, $R$ is the competitive interest rate and $\Pi$ the aggregate operating profits. The price of the final good is normalized to 1.

I assume that the representative household’s period utility is the result of indivisible labor (Rogerson 1988)

$$U(C,1-L) = \log C + \kappa(1-L)$$

with $\kappa > 0$, as the labour disutility parameter and the preference specification allows for balanced growth. The household discounts the future utility by a subjective discount factor, $\beta$.

I can now derive the following optimality conditions:

$$\frac{1}{C} = \beta \frac{1}{C'}(R + 1 - \delta) \tag{15}$$
\[ \frac{1}{C^w} w = \kappa, \] (16)

### 3.2 Production

I can formalize the problem of the competitive firm producing the final good as follows:

\[
\max_{y_j} Y - \int_0^M p_j y_j dj 
\] (17)

subject to \[ Y = \left( \int_0^M y_j \frac{(q-1)}{dj} \right)^\frac{q}{q-1}. \]

The firm maximization problem induces the inverse demand function for the output of the sector \( j \):

\[ p_j = \left( \frac{y_j}{Y} \right)^{\frac{1}{\eta}} \] (18)

Similarly, the maximization problem of the representative firm producing the sector output as follows:

\[
\max_{y_{i,j}} p_j y_y - \sum_{i=1}^{N_j} p_{i,j} y_{i,j} 
\] (19)

subject to \[ y_j = \left( \sum_{i=1}^{N_j} \frac{p_{i,j}^{\frac{1}{\rho}}}{y_{i,j}^{\frac{1}{\rho}}} \right)^{-1} \]

\[ p_j = \left( \sum_{i=1}^{N_j} p_{i,j}^{1-\rho} \right)^{\frac{1}{1-\rho}}. \]

I derive the inverse demand functions for the firm \( i \) in sector \( j \):

\[ p_j = \left( \frac{y_j}{Y} \right)^{\frac{1}{\eta}} \left( \frac{y_{i,j}}{y_j} \right)^{\frac{1}{\rho}} \] (20)

Oligopolistic firms compete à la Cournot in the sector. Each firm \( i \) in sector \( j \) solves the following maximization problem:

\[
\pi_{i,j}^{(f)}(\varepsilon, \varepsilon^f, n^i, n^f) = \max_{y_{i,j}, k_{i,j}, l_{i,j}} (1 - \tau) \left( p_{i,j} y_{i,j} - w_{l_{i,j}} - R k_{i,j} \right) 
\] (21)

subject to \[ y_{i,j} = \varepsilon_{i,j}^{(f)} k_{i,j}^{\alpha} l_{i,j}^{1-\alpha} \text{ with } y_{i,j}, l_{i,j}, \text{ and } k_{i,j} \in \mathcal{R}_+, \]

\[ p_{i,j} = \left( \frac{y_j}{Y} \right)^{\frac{1}{\eta}} \left( \frac{y_{i,j}}{y_j} \right)^{\frac{1}{\rho}}. \]
with \( \tau \) is the flat tax on operating profits. Problem [21] is equivalent to solving the following maximization problem:

\[
\pi_{i,j}(\varepsilon_l, \varepsilon_f, n_l, n_f) = \max \left( (1 - \tau) \left( \frac{y_{i,j}}{y_j} \right)^{\frac{1}{\alpha}} - \frac{y_{i,j}}{y_j} \cdot \frac{y_{i,j}}{\varepsilon_{i,j}} \cdot \left( \frac{1}{\alpha} \cdot \frac{w}{\alpha} \right)^{\frac{1}{\alpha}} \cdot \left( \frac{\alpha}{\alpha - \frac{1}{\alpha}} \cdot \frac{w}{R} \right)^{\frac{1}{\alpha}} \right)
\]

(22)

3.3 R&D games

I assume that firms use labor to produce units of R&D or defensive practices. In particular, I assume that \( l \) units of labor can produce \( \sqrt{2l} \) units of \( x \) units of R&D or defensive practices, such that the cost functions have the following form:

\[
C(x_l^{(f)}) = w^2 (y_l^2) (1 - p_f s) V_l^2(\varepsilon_l, \varepsilon_f, n_l + 1, n_f - 1) + p_f s V_l^2(\varepsilon_l, \varepsilon_f, n_l + 1, n_f - 1)
\]

(23)

Morning. Let \( V_l^1(\varepsilon_l, \varepsilon_f, n_l, n_f) \) and \( V_l^1(\varepsilon_l, \varepsilon_f, n_l, n_f) \) be the value of being leader and follower in the morning. Accordingly, I define \( V_l^2(\varepsilon_l, \varepsilon_f, n_l, n_f) \) and \( V_l^2(\varepsilon_l, \varepsilon_f, n_l, n_f) \) as the values of being leader and follower in the afternoon.

The leader’s optimization problem can be recursively formalized as follows:

\[
V_l^1(\varepsilon_l, \varepsilon_f, n_l, n_f) = \max_{x_l^{(f)} \in [0, \infty)} -w^2 (x_l^{(f)})^2 + \left( \frac{1}{\alpha} \cdot \frac{w}{\alpha} \right)^{\frac{1}{\alpha}} \cdot \left( \frac{\alpha}{\alpha - \frac{1}{\alpha}} \cdot \frac{w}{R} \right)^{\frac{1}{\alpha}} \right)
\]

(23)

The first term inside the brace represents the value of continuing to be a leader in the afternoon with the sector structure unchanged because either the followers failed to innovate or leaders blocked the followers’ innovation through the implementation of defensive practices. The second term indicates the value of being a leader in the afternoon in the case a follower succeeds to innovate and becomes an additional leader in the sector.

Proposition 1 Given \( x^{(f)} \), let \( x_l^{(f)} \) be a symmetric equilibrium of the game represented by the recursive maximization problem [23] then

- \( x_l^{(f)} \) is increasing in \( V_l^2(\varepsilon_l, \varepsilon_f, n_l, n_f) - V_l^2(\varepsilon_l, \varepsilon_f, n_l + 1, n_f - 1) \)
- \( x_l^{(f)} \) is increasing \( x^{(f)} \)
- \( x_l^{(f)} \) is unique.

Proof: see appendix [A.1].

Proposition 1 shows that incentive of the leaders in producing defensive practices has two drivers: protecting rent and credible threat. The first driver highlights the fact that the equilibrium quantities of defensive practices chosen by leaders, \( x_l^{(f)} \), is increasing in the return that leaders have from blocking the innovation: leaders with large market shares produce more defensive practices. The credible threat effect shows as the equilibrium quantities of defensive
practices is increasing in the level of R&D chosen by followers: when the probability that a follower succeeds is high, leaders increase the production of defensive practices.

I can now recursively define the optimization problem of the follower as:

\[
V_{f,1}^f(\epsilon, \epsilon', n, n') = \max_{x_f \in [0, \infty)} -\frac{w}{2} (x_f')^2 + \left\{ (1 - p_{fs}) V_{f,2}^f(\epsilon', \epsilon', n, n') \right. \\
\left. + p_{fs} V_{f,2}^l(\epsilon', \epsilon', n' + 1, n' - 1) \right. \\
\left. + p_{ff} V_{f,2}^l(\epsilon', \epsilon', n' + 1, n' - 1) \right\}
\] (24)

The first term inside the brace represents the value of continuing to be a follower in the afternoon when the sector structure is unchanged because either the followers failed to innovate or leaders blocked the followers’ innovation by implementing defensive practices. The second term indicates the value of continuing to a be a follower in the afternoon facing additional leader. The third term represents the value of winning the contests and becoming an additional leader in the afternoon.

**Proposition 2** Given \(X^l_1\), let \(x_f^*\) be a symmetric equilibrium of the game represented by the recursive maximization problem (24) then

- \(x_f^*\) is increasing in \(V_{f,2}^l(\epsilon, \epsilon', n' + 1, n' - 1) - V_{f,2}^l(\epsilon', \epsilon', n, n')\)
- \(x_f^*\) is increasing in \(V_{f,2}^l(\epsilon, \epsilon', n' + 1, n' - 1) - V_{f,2}^l(\epsilon', \epsilon', n' + 1, n' - 1)\)
- \(x_f^*\) is decreasing in \(X^l_1\)
- given \(X^l_1\), \(x_f^*\) is unique.

**Proof:** see appendix A.2.

Proposition 2 shows that the incentive of the followers in investing in R&D is affected by the return of being leader and the probability of being blocked. First, the equilibrium quantities of R&D chosen by followers, \(x_f\), are increasing in the return of becoming leader: if the productivity of the technology on the frontier is high, then the followers invest more in R&D. Moreover, the probability of being blocked indicates that the equilibrium quantities of R&D chosen by followers are decreasing in the total units of defensive practices implemented by leaders: if the probability of being blocked by leaders is high, the marginal productivity of R&D is low.

**Proposition 3** The game, represented by the recursive maximization problems (23) and (24) admits a unique symmetric equilibrium \((x^{l**}_l, x^{l**}_f)\).

**Proof:** see appendix A.3.

The intuition of proposition 3 is straightforward. The leaders’ symmetric equilibrium of defensive practices is increasing in the choice of the quantity of R&D produced by followers because the credibility of the threat. Conversely, the symmetric equilibrium of the followers is decreasing in the quantity of defensive practices implemented by leaders because the high probability of being blocked discourages the investment.
**Afternoon.** Then, the leader’s optimization problem can be recursively formalized as follows:

\[
V_l^1(\epsilon^l, \epsilon^f, n^l, n^f) = \max_{y^l, x^l, x^f \in \mathbb{R}^+} \epsilon^l \left( x^l^2 \right) - \frac{\beta}{1 + \bar{\epsilon}} (1 - \phi) \left\{ p_{ls} \hat{V}_1(n^l, \epsilon^f, n^l, n^f) + (1 - p_{ls})V_l^1(\epsilon^l - 1, \epsilon^f, n^l, n^f) \right\}
\]  

(25)

with

- \( \hat{V}_1(\cdot) = \sum_{\epsilon_i} p(\epsilon_i | \epsilon^l) \left[ 1_{(\epsilon_j \geq \epsilon^f)} \hat{V}_1(\epsilon_i, \epsilon^f, n^l, n^l + 1) + 1_{(\epsilon_j < \epsilon^f)} \hat{V}_1(\epsilon_i - 1, \epsilon^f, n^l, n^l + n_e) \right] \)
- \( \hat{V}_1(\cdot) = \sum_{\epsilon_i} p(\epsilon_i | \epsilon^l) \left[ 1_{(\epsilon_j \geq \epsilon^f)} V_1(\epsilon_i, \epsilon^f, n^l, n^l + 1) + 1_{(\epsilon_j < \epsilon^f)} V_1(\epsilon_i - 1, \epsilon^f, n^l, n^l + n_e) \right] \)

In the 25, the leader optimally chooses the level of output to produce, the units of R&D, and the productivity cut-off above which implementing the innovation to maximize the sum between the firm’s current profit and the expected discounted value in the morning in the next period conditional on the fact that the sector does not exogenously disappear from the economy with \( (1 - \phi) \) probability. The first term indicates the expected value of loosing the contest. The looser leaders can continue to be leaders if the winner does not implement the innovation. The second term in the brace represents the expected value of winning the patent race. After winning the contest, the leader decides whether to implement the innovation considering the its potential technology gap with the followers and the entry of competitors. The third term represents the value of being leader the next morning when nobody succeeds. Leaders that do not implement the innovation like followers will experience a one step decline in relative productivity as \( \epsilon^l_{-1} \) and \( \epsilon^f_{-1} \).
Proposition 4  Let $x^{l,*}_2$ be a symmetric equilibrium of the game represented by the recursive maximization problem then

- $x^{l,*}_2$ is increasing in $[\tilde{V}_1(n^l, \varepsilon^f, n^l, n^f) - V_1^f(\varepsilon^l_{-1}, \varepsilon^f_{-1}, n^l, n^f + n_e)]$
- $x^{l,*}_2$ is increasing in $[\tilde{V}_1(n^l, \varepsilon^f, n^l, n^f) - \hat{V}_1(\varepsilon^l, \varepsilon^f, n^l, n^f)]$
- $x^{l,*}_2$ is unique.

Proof: see appendix A.4.

Proposition 4 shows that the incentives of the leaders in producing R&D has two drivers: *escape from competition* and *loss of competitiveness*. The *escape from competition* reveals that the equilibrium quantities of R&D chosen by leaders, $x^l_1$, are decreasing in the value of continuing to be a leader with one period depreciated technology. Moreover, the *loss of competitiveness* indicates that the equilibrium quantities of R&D chosen by leaders are decreasing in the value of becoming a follower because another leader implements the innovation.

Similarly, the follower optimization problem can be recursively defined:

$$V^{f,2}(\varepsilon^l, \varepsilon^f, n^l, n^f) = \max_{y^f \in \mathbb{R}_+} \pi^f(\varepsilon^l, \varepsilon^f, n^l, n^f) + \beta \frac{1 + \varepsilon}{1 + \varepsilon'} (1 - \phi) \left\{ (1 - p_{ls})V^{f,1}(\varepsilon^l, \varepsilon^f, n^l, n^f + n_e) + p_{ls} \sum_{\varepsilon'_1 < \varepsilon} p(\varepsilon|\varepsilon^l) V^l_1(\varepsilon^l_{-1}, \varepsilon^f_{-1}, n^l, n^f + n_e) \right\}$$

In (26) the follower optimally chooses the level of output to produce to maximize the sum of the firm’s current profit. The follower does not participate in the contest of the afternoon and survives if no leaders implement the innovation. If $\varepsilon^f = \varepsilon_1$, the follower will experience a decline in productivity that forces it out of the sector. If the productivity of the leaders $\varepsilon^l$ falls below the minimum level required to produce $\varepsilon_1$, then the leaders are forced to leave the economy, and the sector endogenously disappears.

3.4 Entry

**Incumbent Sectors.** Each period, $n_e$, firms can enter the sector after paying the entry cost $c_e = \psi w$:

$$n^e(\varepsilon^l, \varepsilon^f, n^l, n^f) = \left\{ \max_{n \in \{0, 1, \ldots, \infty\}} \text{s.t. } V^l_1(\varepsilon^l, \varepsilon^f, n^l, n^f + n^e) \geq c_e \right\}$$

**New sectors.** The potential entrepreneur’s optimization problem can be formalized as follows:

$$V^e = \max_{x^e} -\frac{w}{2}(x^e)^2 + \frac{x^e}{x^e + R^e} \sum_{i=1}^{N^e} p(\varepsilon_i|\varepsilon_1) V^l_i(\varepsilon^l_1, \varepsilon^f_1, 1, n_e)$$
3.5 Equilibrium definition

At the beginning of each period, a sector is defined by its state vector \((\varepsilon_l, \varepsilon_f, n_l, n_f)\); productivity of leaders \(\varepsilon_l \in E\), productivity of followers \(\varepsilon_f \in E\), number of leaders \(n_l \in \mathbb{N}^+\), and number of followers \(n_f \in \mathbb{N}^0\). I summarize the distribution of firms by a probability measure, \(\mu(\varepsilon_l, \varepsilon_f, n_l, n_f)\), which is defined on a Borel algebra \(S \equiv E \times E \times \mathbb{N}^+ \times \mathbb{N}^0\).

Let \(\mu^0(\varepsilon_l, \varepsilon_f, n_l, n_f)\) and \(\mu^2(\varepsilon_l, \varepsilon_f, n_l, n_f)\) be the time invariant distributions of sectors, respectively, in the morning before entry and in the afternoon.

A stationary equilibrium is a set of prices \((R, w, p^l, p^f)\), a set of allocations \((Y, C, K, y^l, y^f)\), policies \((x^e, x^l_1, x^f, x^l_2)\), and entry dynamic \(n^e\), such that:

1. Given prices, the final and sector good producers maximize their profits.
2. Given \((\varepsilon_l, \varepsilon_f, n_l, n_f)\), \(y^l\) and \(y^f\) maximize profits of the oligopolistic firms in the sectors.
3. \(x^e\) maximizes the value of the potential entrepreneur in the morning \(V^e\).
4. Given \(x^l_1, x^f\) maximizes the value of the follower in the morning \(V^f_1\).
5. Given \(x^f, x^l_1\) maximizes the value of the leader in the morning \(V^l_1\).
6. \(x^l_2\) maximizes the value of the leader in the afternoon \(V^l_2\).
7. \(n^e\) satisfies \(27\).
8. Given prices, \(C\) satisfies \(16\).
9. The real interest rate \(R = \frac{1 + \varepsilon}{\delta} + \delta - 1\).
10. Resource constraint is satisfied:

\[ Y = C + \delta K, \]

where:

\[ K = \int_0^1 (n^l_1 \varepsilon^l_1 + n^f \varepsilon^f) \left[ \frac{n - w}{1 - \alpha} \right]^{1 - \alpha} \mu(\varepsilon^l \times \varepsilon^f \times n^l \times n^f) \]

11. The distributions of firms, \(\mu^0(\varepsilon_l, \varepsilon_f, n_l, n_f)\) and \(\mu^2(\varepsilon_l, \varepsilon_f, n_l, n_f)\), are a fixed point where their transition follow the policy functions, \((x^e, x^l_1, x^f, x^l_2)\), and the entry dynamic \(n^e\).
Table 1: Calibration Benchmark Economy

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Targets</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>Discount factor</td>
<td>0.96</td>
<td>Real interest rate</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Leisure utility</td>
<td>1.25</td>
<td>Total hours worked</td>
<td>0.33</td>
<td>0.325</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Depreciation rate</td>
<td>0.07</td>
<td>Investment/Capital</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>$\eta$</td>
<td>El. of output w.r.t. capital</td>
<td>0.5</td>
<td>Capital/Output</td>
<td>2.30</td>
<td>2.30</td>
</tr>
<tr>
<td>$\eta$</td>
<td>El. sub. between islands</td>
<td>1.05</td>
<td>Value added weighted markup</td>
<td>2.2</td>
<td>2.11</td>
</tr>
<tr>
<td>$\rho$</td>
<td>El. sub. within island</td>
<td>4</td>
<td>Average Markup</td>
<td>1.42</td>
<td>1.435</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Exogenous exit probability</td>
<td>0.05</td>
<td>Median Markup</td>
<td>1.36</td>
<td>1.368</td>
</tr>
<tr>
<td>$\psi$</td>
<td>R&amp;D productivity of follower</td>
<td>0.05</td>
<td>Average Leaders’ sector sale share</td>
<td>0.58</td>
<td>0.573</td>
</tr>
<tr>
<td>$\phi^*$</td>
<td>R&amp;D productivity of leader</td>
<td>0.27</td>
<td>Share of defensive R&amp;D</td>
<td>0.38</td>
<td>0.36</td>
</tr>
<tr>
<td>$\pi$</td>
<td>R&amp;D intensity</td>
<td>0.025</td>
<td>R&amp;D intensity</td>
<td>2.7%</td>
<td>2.65%</td>
</tr>
<tr>
<td>$\mu$</td>
<td>Fraction of wage for entry</td>
<td>0.082</td>
<td>Average number firms per sector</td>
<td>20</td>
<td>20.21</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Effective taxation</td>
<td>0.78</td>
<td>Profit rate</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Growth of technology frontier</td>
<td>0.018</td>
<td>Average productivity growth</td>
<td>0.018</td>
<td>0.018</td>
</tr>
</tbody>
</table>

4 Calibration

The time horizon of the model is one year. The discount factor, $\beta$, is set to have an annual interest rate of 4% as in Gomme et al. (2011). I set the preference parameter of labor disutility, $\kappa$, to get the average hours worked of 0.33. The depreciation rate, $\delta$, is set to match the average investment-to-capital ratio of 0.07, as in Khan and Thomas (2013). The production parameter, $\alpha$, is set to be consistent with the average capital to output ratio of 2.3 in the postwar US economy, as in Senga (2015).

I set the elasticity of substitution between varieties within sector, $\rho$, to match average markups for U.S. in 2015 as estimated in Autor et al. (2020). The destruction probability, $\phi$, is set to match the median markup U.S. in 2015 as estimated in Autor et al. (2020). I set the elasticity of substitution between sectors, $\eta$, to match value weighted markups for U.S. in 2015, as estimated in Autor et al. (2020). I set the entry cost, measured in labor units, $\psi$, to target the average number of oligopolistic firms per sector of 20.

I set the parameter that governs the productivity of followers’ R&D $R_f$ to match the sector average leaders’ sale shares with sector average top4 sale shares among top20. In particular, considering the year 2015, the share of the top4 among the top20 was about 60 and 57 % for the manufacturing and service 4 digit sectors, as estimated in Autor et al. (2020). Finally, I obtain the target by weighting for the gdp share of manufacturing and non-manufacturing sectors. I set the parameter that governs the productivity of the leaders’ R&D productivity $R_l$ by targeting the ratio of defensive over total leaders’ R&D expenditures to be 0.35. I follow Akcigit and Ates (2019) that, using data from the U.S. Patent and Trademark Office (USPTO) for the period 1980-2015, defines as one of the proxies of

\[ \text{Share top4 among top20} = 0.12 \times 60 + 0.88 \times 57 \]
the defensive behaviour of the firms, the share of citations of the patents that cites patents from the firm’s existing portfolio. Indeed, the production of those patents may represent the intention of the leaders to create a dense web of patents to make the catch-up difficult. Hence, I assume that the share of self-citations perfectly reflects the relative effort of the leaders in developing defensive practices. I set the parameter that governs the productivity of the potential entrepreneurs’ R&D productivity \( R_e \) to match the ratio of R&D expenditure over gdp in 2015 as reported by National Science Foundation. I set the mass of potential entrants \( \Sigma \) to have the total mass of sector \( M \) equals to 1.

The growth of the frontier technology \( \bar{\varepsilon} \) targets the average labor productivity as in Sedláček (2020). Finally, I set the flat tax on operating profits parameter to match the profit rate for the U.S. in 2015 provided in FRED.

5 Steady State: Sector Heterogeneity and Decisions

I begin with describing the economy where sector leaders implement defensive practices. From Figure 3, the model replicates the inverted-U relationship between the sector expected R&D intensity and the level of competition approximated with the Herfindahl index, mimicking the evidence found in the data in Aghion et al. (2005). This quadratic relation relationship is built on the different correlations between the market share and concentration that leaders and followers have.

As reported in table 5, both the leaders and followers show that the firm’s productivity improving R&D intensity is negatively related with market share, supporting the findings of Akcigit and Kerr (2018) and Akcigit (2009). However, leaders’ market share is positively related with the concentration. In concentrated sectors in which few and very productive leaders hold almost the whole market shares, followers receive a high return in reaching the technology frontier since it would expand their market share and, consequently, their profit. Leaders have a very weak incentive in investing in productivity improving R&D since the return will be relatively low as already predicted by the Schumpetarian model of Aghion and Howitt (1992). Moreover, leaders have to consider the positive technology spillovers that their innovations can generate toward the potential entrants. As explained below, this model feature acts as an additional factor that contributes to the leader’s reduction of the incentive to invest in productivity improving R&D when it already has a large market share. In competitive sectors, because either there is a huge technology gap between leaders and followers or there are already several firms on the technology frontier, followers have a weak incentive in investing to reach the frontier. Instead, leaders driven by the escape from competition effect, have a strong incentive in investing in productivity improving R&D because the winner increases its profit since it becomes relatively more productive with respect to the other leaders converted into followers. The leaders’ gap between post-

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12In the model, the R&D expenditures incorporates also the expenditures to produce defensive practices.
13In particular, I target the profit per unit of real gross value added to nonfinancial corporate business: corporate profits after tax with IVA and CCAdj (unit profits from current production). In the model, the profit rate is calculated as follows:

\[
\text{Profit rate of the model} = \frac{\text{Operating profits after tax}}{\text{Y}}
\]

14A period is defined as the time between two consecutive production activities, and it comprises morning and afternoon. So, I consider the Herfindahl index and total revenues of the sector during the production in period t, and I calculate the expected R&D expenditures between t and t+1. The R&D expenditure includes defensive R&D expenditures.
innovation and pre-innovation rent is bigger because both the pre-innovation rent is low, and post-innovation rent is high, given the weak the technology spillover generated toward the potential entrants.  

The firms’ policy functions reflect the previous correlations. First, looking at Figure 4, the choice of investment of the leader becomes a trade-off between the present and future competition. Indeed the leader that innovates forces the followers out of the sector and converts the current leaders into followers, but concurrently, she generates positive externality toward new entrants whose productivity will be equal to the current leader’s productivity depreciated by one period. In this way, innovations may end up with creating an even more competitive sector with a smaller market share for the leader. Indeed, in sectors with huge productivity gaps between leaders and followers, it is likely that the winner leader will draw a productivity associated with the innovation that decreases the technology gap with the followers and, consequently, it refuses to implement it. Anticipating it, leaders reduce the productivity improving R&D efforts when the technology gap increases. Second, I can note from Figure 5 that the productivity improving R&D intensity of the leader is increasing in the number of leaders playing the contest for two reasons. First, a high number of leaders means low revenues, and consequently, the shares of expenditures on revenues are high. Second, a high number of leaders generates a high incentive to produce more units of productivity improving R&D because of the fall in the pre-innovation rent. This second mechanism is overwhelmed by the congestion effect when the number of leaders is above a certain threshold, and the units of productivity improving R&D decrease. However, the total units of productivity improving R&D produced by the leaders are increasing in the number of players that are in the contest. More generally, Figure 13 confirms that the average leader’s productivity improving R&D intensity and production is high in almost neck-and-neck sectors, where the escape from competition effect is strong, and the technology spillovers are weak.

Focusing on the R&D decisions of the followers, they face different incentives. First, Figure 6 shows that the follower’s R&D intensity is increasing in leader’s productivity for two reasons. First, high leaders’ productivity means low revenues, and consequently, the the shares of expenditures on revenues are high. Second, a huge technology gap incentivizes the production of R&D because the return of reaching the frontier is high. However, when leaders’ productivity is very low, the followers’ R&D is decreasing in the technology gap because the probability that a leader innovates and forces the followers out of the sector is decreasing in leaders’ productivity. To survive, followers increase their effort to become leader and to play the contest in the afternoon. Figure 7 indicates that the R&D intensity of followers is decreasing in the number of leaders because the return of reaching a crowded frontier is low. Second, Figure 8 highlights that the R&D intensity of the follower is decreasing in the number of firms participating in the contest due to the congestion effect. Although the total units of R&D are increasing. Figure 12, that reports the average units of R&D produced by the follower for each technology gap, indicates that the R&D effort is increasing in the productivity of the frontier.

15 The technology spillovers generated by leaders’ innovations toward the potential entrants are increasing in firms’ size. This modeling choice supports the evidence found in Bloom et al. (2013) where larger firms have a bigger gap between private and social return.

16 When the total units of productivity improving R&D produced by the leaders are high, the marginal productivity of the R&D of the leader decreases.
Focusing on the leader’s defensive R&D intensity, from Figure 9, the intensity is initially decreasing in the technology gap for three reasons. First, as explained before, when leaders’ productivity is low, followers’ R&D is decreasing in leaders’ productivity, so leaders counteract by increasing the production of defensive practices. Second, leaders want to avoid additional competition in the contest of the afternoon since it reduces the probability of winning it and, consequently, increases the probability to leave the economy within few periods. Third, in neck-and-neck sectors, leaders’ market share is small, and the defensive R&D expenditure as share of revenues are high. The defensive R&D intensity is increasing in the technology gap because of two reasons. First the reduction in the leaders’ rent due to the catch-up is increasing in the technology gap between leaders and followers. Second, leaders anticipate that an additional leader on the frontier lead them to play the contest in the afternoon facing the possibility to loose their position of advantage because the winner leader will implement the innovation with high probability. Indeed, from Figure 9 this second incentive falls when the leader’s productivity is very high, and the defensive R&D decreases. In sectors with high technology gap, the probability that a winner leader implements the innovation is low because the probability of drawing a productivity that enlarges the gap regarding the followers is low. However, figure 15 which reports the average leader’s production of defensive practices for each technology gap, indicates that the leader produces more defensive practices as the technology gap becomes wider. Figure 10 shows how leaders’ defensive R&D intensity is decreasing in the number of leaders. First, a crowded frontier reduces leader’s incentive to protect their market shares. Second, as shown in Figure 7, followers’ R&D choice is decreasing in the number of leaders in the sector; consequently, leaders tend to reduce the production of defensive practices. Third, leaders are playing a public good game that induces to the problem of free-riding. Finally, the production defensive practices are increasing in the number of followers in the sector. A high number of followers means a high total production of R&D of the follows and potentially a high probability that a follower succeeds in catching up the frontier (Figure 11). Leaders counteract to this threat by increasing the production of defensive practices.

Regarding the dynamic of the entry, figure 14 shows that the entry is increasing in the productivities of the followers and leaders of the sectors. The reason is twofold. First, high followers’ productivities mean high current profits. Second, high leaders’ productivities mean high future profits given the possibility of succeeding in imitating the leader technology. This second dynamic supports the findings of Klepper (2015), where new successful products attract new firms trying to imitate it. Finally, from Figure 10 the total R&D of followers and the total defensive R&D of the leaders are higher in sectors with a high technology gap. Given these two opposite forces, the probability that a follower catches up is higher in sectors with mean values of the technology gap.

Finally, the structure of the model can create a sector cycle where the level of concentration can fluctuate over time. A very concentrated sector attracts a high number of entrants that generate a high level of innovation reducing the concentration due to the catch-up. When the sector becomes competitive, the pre-innovation rent falls and leaders start producing productivity improving R&D and implementing a new innovation by re-creating a more

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17 The correlation between the number of entrant firms and log-Herfindahl index is 0.41.
concentrated sector.

| Table 2: Comparison of the economies: With and without defensive behavior |
|---------------------------------|-----------------|-----------------|-----------------|
|                                | With defensive  | Without defensive | Without defensive |
|                                | practices       | practices        | practices and     |
|                                |                 |                 | production       |
| Mass of varieties $M$          | 1.0             | 0.979           | 1.0             |
| Aggregate output $Y$           | 1.0             | 0.775           | 1.73            |
| Endogenous Productivity        | 1.0             | 0.923           | 1.25            |
| Value-weighted Margins          | 2.39            | 1.67            | 1.67            |
| Average Margins                | 1.475           | 1.405           | 1.406           |
| Median Margins                 | 1.398           | 1.308           | 1.368           |
| Average number of firms in the sector | 22.09   | 22.09           | 22.09           |
| Average number of leaders in the sector | 2.36   | 2.64            | 2.63            |
| R&D intensity $\%$             | 2.45            | 2.12            | 2.15            |
| leaders' R&D intensity $\%$    | 1.61            | 1.61            | 1.61            |
| followers' R&D intensity $\%$  | 3.7             | 3.4             | 3.4             |
| Leaders' productivity improving R&D intensity $\%$ | 1.1   | 0.9             | 0.9             |
| R&D choice of potential entrepreneurs $p^*$ | 0.175 | 0.10            | 0.10            |
| Share of $Y$ produced by leaders $\%$ | 36.4  | 52.7            | 52.7            |
| Leaders' relative size         | 10.27           | 8.4             | 8.1             |
| Average probability of catch-up | 0.0196          | 0.0148          | 0.0250          |
| Sector average probability of catch-up | 0.36       | 0.49            | 0.49            |
| Average leaders' persistence within 5 periods | 0.42   | 0.35            | 0.35            |
| Sector average leaders' turnover within 5 periods | 0.55   | 0.59            | 0.59            |
| Herfindahl index               | 0.206           | 0.13            | 0.13            |
| Profit rate                    | 0.090           | 0.070           | 0.040           |

Note: The first column on the left reports the aggregate quantities of the Benchmark economy in which leaders can produce defensive R&D. The second column reports the aggregate quantities of the economy without defensive behavior. The third column reports the aggregate quantities of the economy without defensive behavior and production specialization. Aggregate output and endogenous productivity are normalized to 1 in the Benchmark economy.

6 Isolating the Effect of Defensive Practices

In this section, I first present the results from the counterfactual analysis in which the leaders are prevented from implementing defensive R&D to slow down the followers’ catch-up. Also, I isolate the mechanisms through which the defensive behavior affects the aggregate results.

6.1 The Effect of Defensive behavior

Focusing on the columns of Table 2 which respectively report the aggregate quantities of the benchmark economy and of the economy in which leaders are restricted from implement defensive practices, observably, firms’ defensive behavior improves the aggregate output and endogenous productivity respectively, by 24.5 and 17.7%. The benchmark economy is characterized by a higher R&D intensity, concentration, larger leaders, and mass of sectors.

First, I can note that the R&D intensity of the economy without defensive behavior drops to 2.12% that is 0.20% percentage points below the intensity of the benchmark economy net to expenditures for defensive R&D. The reduction in R&D intensity is driven by the fall in the average leaders’ intensity that that decreases from 1.13 to 0.9% and by the fall in the average followers’ intensity that diminishes from 3.7 to 3.4%.

I calculate TFP as the Solow residual, $Y/(K^{\alpha}L^{1-\alpha})$, given aggregate output ($Y$), capital ($K$), and labor ($L$).
The leaders’ possibility of implementing defensive practices raises the sectors’ concentration, thereby inducing the benchmark economy to have a value-weighted Herfindahl index almost 25% exceeding the economy without defensive practices. Moreover this reduction in competition induces a higher value-weighted markup in the benchmark economy. Observably, the defensive behavior mainly affects the value-weighted markup leaving relatively unchanged the median and the average markups.

Focusing on the firms’ size, the representative leader’s market share is substantially larger in the benchmark economy in which a leader controls almost 25% of the market share regarding the economy without defensive practices in which the market share of the representative leader falls to 20%. The market share of the representative follower is similar between the two economies in which they are around 2.5%. Accordingly, the representative leader’s relative size regarding the representative follower is 25% higher in the benchmark economy.

Finally, the benchmark economy is associated with 2.1% additional mass of sectors compared to the economy without defensive behavior. This reflects the higher R&D effort of the potential entrepreneurs because the possibility to implement defensive practices increases the post innovation rent because the leaders can better protect their position by preventing the imitation of the followers.

Furthermore, I explain the mechanisms through which the possibility to implement defensive practices affects the aggregate quantities such as concentration, R&D intensity, innovation intensity, and aggregate output. In particular, the main goal is to ascertain whether the mechanisms mimic those embodied in the “superstar firms theory” of Autor et al. (2020) where there is a reallocation of the output toward the firms that adopt more productive technologies or reflect the production specialization driven by the rise in post-innovation rent of the potential entrepreneurs.

### 6.2 Inspecting the mechanisms

The possibility for firms to implement defensive practices may affect firms’ investment decisions and, consequently, innovation intensity through a direct and indirect effect.

The direct effect for the leaders and the potential entrepreneurs indicates that defensive behavior increases investments in productivity improving R&D or in the creation of new products because it increases the post-innovation rent that derived from innovation due to the rise in the appropriability. The direct effect for the followers refers to the fact that defensive practices may promote R&D investments because it increases the return on being on the sector frontier. This effect may resemble the trickle-down incentive studied in Acemoglu and Akcigit (2011), with the difference that the level of protection is endogenously chosen by the leader, and it does not dependent on the leads of the leader.

Conversely, the defensive behavior generates also an indirect effect for leaders that leads to a reduction of the leaders’ incentive to invest in productivity improving R&D. Indeed, the defensive behavior may reduces number of followers that catches up weakening the escape from competition effect. Moreover, the defensive behavior generates also an indirect effect for the followers that reduces their R&D and innovation intensity for two reasons. First, the

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19I define the representative leader as the leader of the representative sector, which comprises a number of leader equals to the average number of leaders and a number of followers equals to the average number of followers among sectors in the economy.
defensive behavior acts as a negative investment specific shock that reduces the productivity of R&D. Second, the reduction in the followers’ R&D productivity leads to the reduction in the units of R&D.

Comparing the policy functions in Figure 18, the leader’s productivity improving R&D increases with the introduction of the defensive practice because it raises the post-innovation rent allowing the leader to maintain a dominant position for a longer period. However, Figure 18 shows that high concentrated sectors may reduce the total investment of the leaders and, consequently, the total innovation intensity because the escape from competition effect is weaker.

Under this framework, the defensive behavior may have positively affected the aggregate output and endogenous productivity through two mechanisms that reflect the direct effect.

First, through the direct effect, the defensive behavior may spur R&D and innovation intensity thereby inducing the reallocation of output toward very large and productive firms. This mechanism can be seen close to the one embodied in the “superstar firms theory” of Autor et al. (2020) in which the toughness of the market due to globalization pushes the reallocation of output toward the most productive and high markup firms.

Second, through the direct effect, defensive behavior incentivizes the R&D of the potential entrepreneurs, and consequently, it promotes the sector varieties’ expansion that increases the productivity of factors of the economy through the specialization of production. Indeed, the post-innovation rent of the potential entrepreneur increases because the entrepreneur will enjoy a dominant position for a longer period of time since it can defend it by implementing defensive practices. This mechanism is close to the idea of growth of Romer (1990) and Ethier (1982) based on the specialization of the production in which “the discovery on how to produce a new good takes a tiny share of the market from each existing producer, while increasing the overall size of the market”, as explained in Jones (2019). Furthermore, I investigate whether higher of R&D intensity of the followers of the benchmark economy reflects the higher return of reaching the sector frontier.

Comparing the average production and intensity of R&D among followers that belong to sectors with different technology gaps between the two economies in Figure 19, the average production and intensity of the followers are lower in the benchmark economy regarding without defensive behavior. The higher R&D intensity of the followers in the benchmark economy is mainly explained by the shift in the distribution of the mass of sectors that moves toward those regions where concentration is high and followers’ productivity is low, and consequently, the followers’ intensity is high as documented in Figure 20. Even though the total quantity of followers’ R&D is higher in some kinds of sectors with defensive behavior as documented in Figure 21, the average innovation intensity is lower. In particular, the sector average catch-up probability is 26% lower in the benchmark economy.

Figure 22 that reports the average productivity improving R&D intensity among leaders that belong to sectors with the same technology gaps, shows that the direct effect of the defensive behavior can increase the intensity and production of R&D only in the neck-and-neck sectors. Similarly, the higher productivity improving R&D intensity partially reflects the shift in the distribution of sectors toward those regions in which the leaders are less productive with a high R&D intensity. The lower catch-up probability of benchmark economy leads to a lower average number
of leaders per sector that triggers both the reduction in the leader’ productivity improving R&D\textsuperscript{20} intensive margin, and the reduction of the total leaders’ innovation intensity (Figure\textsuperscript{22}, revealing that the average total quantity of productivity improving R&D decreases for each technology gap except in the high productive neck-and-neck sectors.

In benchmark economy, the shift in the distribution of sectors driven by the lower leaders’ innovation intensity makes firms adopt less productive technologies (Table\textsuperscript{8}). The fact that with defensive behavior firms adopt less productive technology does not only depend on the lower productivity of the technologies of followers, but it also reflects the adoption of less productive technologies of leaders, as reported in the decomposition of the total output produced by leaders in the Table\textsuperscript{9}.

After investigating how the defensive behavior affects the technology adoption across firms, I explore why the share of leaders’ output is larger in the benchmark economy. Table\textsuperscript{10}, which compares the shares of output produced by the leaders among firms that belong to sectors characterized by the same leader’s productivity, in the benchmark economy, shows that the average share is almost unchanged among firms that belong to sectors with both leaders and followers. To understand why the share of leaders’ output rises, I need to consider also those sectors in which there are no followers because the technology available to the entrants have productivity ε\textsuperscript{f}\textsuperscript{21}. With the possibility to produce defensive practices, to further enlarge their market share and exponentially increase their profit, leaders, currently enjoying large market shares, find optimal to prevent followers from catching up until the depreciation of the technology forces the followers to leave the sectors.

Another important feature of the benchmark economy is huge gap between value weighted and average markups. In the benchmark economy, the value-weighted markups can increase through two mechanism. First, the rise can be explained with the reduction in the average number of leaders per sector that is not compensated by a substantial rise in the number of followers. Second, the rise can come from the higher markups and mass of those sectors in which entrants lack the technology to immediately produce. The table\textsuperscript{14} which reports the value weighted markups among firms that belong to sectors characterized by the same leaders’ productivity, confirms that the second mechanism mainly explains why the benchmark economy has a higher value-weighted markups than the economy without defensive behavior. Indeed, considering just the firms belonging to sectors with ε\textsuperscript{f} > ε\textsubscript{0}, the rises in value weighted markups are quite mild. The main reason of the higher value weighted markup is because, in the benchmark economy, the mass of sectors characterized by ε\textsuperscript{f} = ε\textsubscript{0} is 15% compared to 8% of the economy without defensive practices (Table\textsuperscript{12}). Conversely, considering Table\textsuperscript{14}, I can see that defensive behavior affects mildly the average markup.

The higher gap between value weighted and average markups of the benchmark economy translates into a higher dispersion of firms’ size distribution and labor productivity. The benchmark economy is associated with a percent deviation of 174 of the firms’ size distribution compared with the 147 of the economy without defensive behavior (Figure\textsuperscript{17}). Allowing the firms to implement defensive behavior leads to a 12% rise of the skewness of the firms’ size distribution that reflects the higher mean and the lower median size. More specifically, in the benchmark economy

\textsuperscript{20}Except in neck-and-neck sectors with low productivities of leaders and followers.

\textsuperscript{21}Followers need to succeed in imitation before to start to produce. In principle, the model can have sectors without followers with ε\textsuperscript{f} > ε\textsubscript{0}. However, the equilibrium distributions are characterized by all sectors without followers having ε\textsuperscript{f} = ε\textsubscript{0}.
the reduction in competition increases the size of the largest firms. Considering Table 6 which shows the output share of firms by size, the rise in the market share of large firms is concentrated among the top 5.0% firms.

In principle, the recent rise of pervasiveness of firms’ defensive behavior highlighted by Akcigit and Ates (2019) and Covarrubias et al. (2020) could help to explain the evidences of Autor et al. (2020) and Hartman-Glaser et al. (2019) that show that large firms have grown in size relative to small firms, and those firms tend to operate in more concentrated sectors. The higher dispersion of firms’ size distribution of the benchmark economy translates also into a higher dispersion of the between-firm productivity measured as log revenue per worker that is around 13% deviation compared to 8% deviation of the economy without defensive behavior. In this way, the recent rise of pervasiveness of defensive practices could help to explain the dispersion of log revenue per worker found by Barth et al. (2016).

Besides the larger leaders’ size, the possibility to implement defensive practices leads to a reduction of 15.5% of the sector average leaders’ turnover within five period, which quantitatively supports the findings of Covarrubias et al. (2020) in the last two decades. From Table 7 the higher persistence of being a leader is driven by the higher persistence of largest 5.0% of leaders. In this way the recent rise of pervasiveness of defensive behavior could help to explain the rise in persistence of firms in the Top 500, as shown in Autor et al. (2020).

Finally, the increases in output and endogenous productivity are totally driven by the production specialization since firms, both leaders and followers, adopt less productive technologies in the benchmark economy compared to the economy without defensive practices. A large share of output is produced by larger firms whose size derives from the possibility to prevent competition.

7 Markups and Defensive Behavior

In this section, I examine how the distribution of markups may reveal the firm-level and the macroeconomic implication of firms defensive behavior. To implement the study I set \( \eta \), the parameter that governs the elasticity of substitution among sectors and the monopolistic markups, equals to 1.35 to match the value of 1.56 as the value weighted markups for U.S. in 1980, as estimated in Autor et al. (2020).

Finally I compare the macroeconomic effects of the rise of product substitutability within sectors with the effects of fall of the substitutability between sectors. The objective is to understand whether the Superstar firms’ Theory of Autor et al. (2020) in which the rise of competition increases concentration by shrinking and exiting the low productive firms, can explain the trends of the last two decades of the U.S. economy in R&D and defensive intensity as well as the markups distribution.

Finally, I compare the aggregate outcomes of economies characterized by different values of substitutability between and within sector.

\(^{22}\) The target is obtained by averaging the four estimation provided in Autor et al. (2020).

\(^{23}\) “...greater competition (meaning higher substitutability between varieties of goods) will tend to make markets tougher causing low productivity firms to shrink and exit.”
<table>
<thead>
<tr>
<th>Table 3: Comparison of the economies: Low and high η</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Models</strong></td>
</tr>
<tr>
<td><strong>Low η</strong></td>
</tr>
<tr>
<td><strong>1980</strong></td>
</tr>
<tr>
<td>Value-weighted Markups</td>
</tr>
<tr>
<td>Average Markups</td>
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<tr>
<td>Median Markups</td>
</tr>
<tr>
<td>Number of Firms</td>
</tr>
<tr>
<td>Number of Leaders</td>
</tr>
<tr>
<td>R&amp;D intensity %</td>
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<tr>
<td>Long-run R&amp;D intensity %</td>
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<tr>
<td>Followers' R&amp;D intensity %</td>
</tr>
<tr>
<td>Leaders' R&amp;D intensity %</td>
</tr>
<tr>
<td>Share of defensive R&amp;D %</td>
</tr>
<tr>
<td>Share of defensive R&amp;D %</td>
</tr>
<tr>
<td>Leaders' productivity improving R&amp;D intensity %</td>
</tr>
<tr>
<td>Benchmark economy</td>
</tr>
<tr>
<td>Share of Y produced by leaders %</td>
</tr>
<tr>
<td>Sector average of leaders' sector share %</td>
</tr>
<tr>
<td>Leaders' relative size</td>
</tr>
<tr>
<td>Followers' average probability of catch-up</td>
</tr>
<tr>
<td>Sector average probability of catch-up</td>
</tr>
<tr>
<td>Average leaders' persistence within 5 periods</td>
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<tr>
<td>Sector average leaders' turnover within 5 periods</td>
</tr>
<tr>
<td>Herfindahl index</td>
</tr>
<tr>
<td>Profit rate</td>
</tr>
</tbody>
</table>

**Note:** The table shows the results obtained by solving different models. The first column on the left reports the aggregate quantities of the Benchmark economy. The second column reports the aggregate quantities of the high η economy with defensive behavior.

### 7.1 Steady State comparisons

From Table 3, the fall of substitutability between sectors leads to an economy with a lower R&D intensity whose value is surprisingly close to 2.2% of the U.S. economy in 1980. This value mainly reflects the lower R&D intensity of the followers. Considering Figure 24, that compares the average R&D intensity among followers that belong to sectors with the same leaders and followers’ productivity, I note that the followers’ R&D intensity is higher in the economy with high substitutability. The reason is that the average size of followers is smaller in the low specialised economy given the higher number of leaders per sector (Figure 25) and the higher substitutability that leads to an output reallocation toward the firms on frontier of the sector. The higher R&D intensity of the followers of the benchmark economy is explained by the shift of the distribution of sectors toward those regions in which followers’ productivity is low and intensity is high.

The rise in the value of η reduces the intensity and the production of defensive R&D (Figure 26). When the substitutability between sectors is low, the competition between firms is within sector. This leads leaders to strongly defend their relative advantage toward the direct competitors with the production of defensive practices. Moreover, in benchmark economy, the distribution of sectors is shifted toward the regions in which followers are less productive and where the defensive behavior is more pervasive.

In the benchmark economy for each technology gap, the total quantity of followers’ R&D is higher in the sectors of low followers’ productivities, given the higher average number of followers (Figure 27). Due to the higher degree of competition of the low specialised economy, the entry of firms drops in the sectors in which followers have low productivities (Figure 25). However, in the benchmark economy, the average probability of catch-up is 5.5% lower.
due to the more intense production of defensive practices.

Considering Figure 28 in the high \( \eta \) economy, the average productivity improving intensity and production of R&D are higher, except in high productivity neck-and-neck sectors. The higher substitutability between sectors stimulates leaders to adopt more productive technologies. Likewise, the higher productivity improving R&D intensity of benchmark economy reflects the shift in the distribution of the sectors toward those regions in which the leaders are less productive and have high R&D intensities. The lower catch-up probability of the benchmark economy leads to a lower average number of leaders per sector that reduces the total leaders’ productivity improving R&D.

The shift in the distribution of the sectors driven by the lower leaders’ innovation intensity of the benchmark economy reflects that firms adopt less productive technologies, as documented by the first columns of Table 8. In the benchmark economy, the firms’ adoption of less productive technologies depends on the productivity of the technologies adopted by followers and the adoption of less productive technologies by leaders (Table 9).

In the benchmark economy, although the leaders adopt less productive technologies, the aggregate share of output produced by leaders is larger. Considering Table 10 in the two economies, the shares of output produced by leaders among firms that belong to sectors with both leaders and followers are roughly constant. Also, considering sectors without followers, in the benchmark economy, the larger output share of leaders is because of more concentrated sectors in which followers lack the technology to produce (Table 12).

Another important difference between the two economies is the different value weighted markup. This difference is driven by the markups, mass, and firm size of the firms operating in concentrated sectors without followers. Table 13 shows the results of the decomposition exercise that isolates the different sources explaining the different value-weighted markups for these two economies. First, looking at the second column of table 13 which reports the value weighted markups obtained using the values of markups and size of the high \( \eta \) economy with the distribution of the benchmark economy, I can note that almost 4% of the difference is due to the higher concentration of the sectors of the benchmark economy. Second, looking at the third column of table 13 which reports the value weighted markups obtained by using the values of markups of the high \( \eta \) economy and the sector distribution and the size of the benchmark economy, I deduce that 7.4% of the difference is because of the higher size of the high markups firms in the benchmark economy. The intuition is that low productive monopolistic firms are larger in the economy with lower substitutability. Finally, the 88% of the difference value-weighted markups between the high and low \( \eta \) economies is due to the reduction of substitutability between sectors that raises the monopolistic markups of the economy (the fourth column of Table 13).

Finally, in the benchmark economy, the dispersion of firms’ size distribution is higher, as I can note from figure 23 for three different reasons. First, the low specialised economy has the sectors distribution shifted toward those regions of high productive neck-and-neck sectors (Figure 28). Second, in the economy with high sector substitutability, there is a lower number of firms entering sectors with a huge technology gap (Figure 27). Last in the low specialised economy, the relative size of large firms tends to be smaller as I can infer from comparing the output share of the largest 5% firms shown in Table 6. As I can observe from comparing the mass of sectors without followers of the
two economies in Table 12, the high $\eta$ economy has a lower mass of sectors without followers, thereby reducing the relative size of the large firms (Table 9).

The reduction of substitutability between sectors increases the competition between firms within sectors. Rising the monopolistic markups increases the incentives of the leaders to maintain their relative advantage toward the direct competitor within sectors, and consequently, it spurs the production of defensive practices and it reduces the incentive of leaders to invest in productivity improving R&D. The sectors’ distribution shifts toward the regions where firms are less productive and have a higher R&D intensity. The higher dispersion of the firms’ size distribution of benchmark economy reflects the facts that the economy has a larger share of output produced by larger firms whose size is derived from the possibility to prevent competition, and its average size of followers is 4% lower. Moreover, the lower competition between sectors leads monopolistic firms to charge higher markups enlarging gap between value weighted and average markup.

Table 4: Comparison of the economies with and without defensive behavior: High $\eta$

<table>
<thead>
<tr>
<th></th>
<th>With defensive practices</th>
<th>Without defensive practices</th>
<th>Without defensive practices and production specialization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of varieties $M$</td>
<td>1.0</td>
<td>0.979</td>
<td>1.0</td>
</tr>
<tr>
<td>Aggregate output $Y$</td>
<td>1.0</td>
<td>1.17</td>
<td>1.49</td>
</tr>
<tr>
<td>Endogenous Productivity</td>
<td>1.0</td>
<td>1.005</td>
<td>1.110</td>
</tr>
<tr>
<td>Value-weighted Markups</td>
<td>1.56</td>
<td>1.49</td>
<td>1.30</td>
</tr>
<tr>
<td>Average Markups</td>
<td>1.38</td>
<td>1.36</td>
<td>1.38</td>
</tr>
<tr>
<td>Median Markups</td>
<td>1.35</td>
<td>1.35</td>
<td>1.36</td>
</tr>
<tr>
<td>Average number of firms in the sectors</td>
<td>25.57</td>
<td>25.42</td>
<td>23.35</td>
</tr>
<tr>
<td>Average number of leaders in the sectors</td>
<td>2.47</td>
<td>2.15</td>
<td>2.33</td>
</tr>
<tr>
<td>R&amp;D intensity %</td>
<td>2.05</td>
<td>1.80</td>
<td>1.80</td>
</tr>
<tr>
<td>followers' R&amp;D %</td>
<td>1.29</td>
<td>1.32</td>
<td>1.32</td>
</tr>
<tr>
<td>leaders' R&amp;D %</td>
<td>2.6</td>
<td>2.60</td>
<td>2.61</td>
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<tr>
<td>leaders' protection against %</td>
<td>0.55</td>
<td>0.44</td>
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<tr>
<td>R&amp;D choice of potential entrepreneurs $x^e$</td>
<td>0.035</td>
<td>0.094</td>
<td>0.0</td>
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<tr>
<td>Share of Y produced by leaders %</td>
<td>50.9</td>
<td>45.35</td>
<td>49.70</td>
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<td>Leaders' relative size</td>
<td>8.81</td>
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<td>7.54</td>
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<td>Average probability of catch-up</td>
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<td>0.0230</td>
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<tr>
<td>Sector average probability of catch-up</td>
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<td>0.48</td>
<td>0.48</td>
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<tr>
<td>Average leaders’ persistence within 5 periods</td>
<td>0.40</td>
<td>0.35</td>
<td>0.35</td>
</tr>
<tr>
<td>Sector average leaders’ turnover within 5 periods</td>
<td>0.53</td>
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<tr>
<td>Herfindahl index</td>
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<tr>
<td>Profit rate</td>
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<td>0.002</td>
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</tbody>
</table>

Note: The first column on the left reports the aggregate quantities of the economy in which leaders can produce defensive R&D. The second column reports the aggregate quantities of the economy without defensive behavior. The third column reports the aggregate quantities of the economy without defensive behavior and production specialization. Aggregate output and endogenous productivity are normalized to 1 in the benchmark economy.

7.2 The effect of Defensive behavior with high $\eta$

Focusing on the first columns on the left and right of Table 4, which report the aggregate quantities of the economy with and without defensive practices, the possibility to implement defensive practices reduces the aggregate output and endogenous TFP, respectively, by 17 and 6.5%.

The effect of defensive behavior on followers’ R&D intensity agrees with the findings of the benchmark economy (Figure 29). Consistently, with the benchmark economy, I conclude that the higher followers’ intensity of the economy with defensive behavior is because more sectors are in the regions in which followers have low productivities and high
intensity. Given the higher average number of followers, Figure 31 shows that the sector average total production of followers’ R&D is higher in the economy with defensive behavior; regarding the absence of defensive practices, it delivers a higher probability of catch-up.

Conversely, the leader’s production and intensity of productivity improving R&D generally drop when the leaders are restricted from implementing defensive practices in the neck-and-neck sectors as in economy with low substitutability (Figure 30). For each technology gap, the total productivity improving R&D produced by leaders is higher in the neck-and-neck sectors in the economy with defensive practices because of the intensive margin. However, the indirect effect of defensive behavior is stronger than that of direct, and the leaders’ innovation intensity is higher in the economy without defensive behavior since leaders tend to adopt more productive technology (Table 9).

In the low specialised economy, after the removal of the defensive practices, the gap between value-weighted and average markups is smaller compared to the benchmark economy. The reason is that in concentrated sectors of the low specialised economy, the markups charged are lower than those charged in concentrated sectors of the economy with low substitutability, and consequently, the fall in the mass of concentrated sectors induces a milder reduction in the value-weighted markup.

Regarding the firms’ size distribution, in the economy with high sector substitutability, after the removal of defensive practices, the fall in the dispersion is milder (Figure 23). This is due to the different impacts that the removal of defensive behavior have on the average followers’ size.

Finally, the lower monopolistic markups reflects the weaker effect that the production specialization has on the factors’ productivity and, consequently, on the economy’s aggregate output. The fall in sectors’ concentration and the adoption of more productive technologies due to the absence of defensive practices increases the output and endogenous productivity, although the economy with defensive behavior has 2% of additional sector varieties.

7.3 Rise or fall of the level of competition

The Figure 32, which shows the different levels of R&D intensities of economies characterized by different levels of substitutability between and within sectors, indicates that the greater competition within sectors increases the R&D intensity of the economy such as the reduction of substitutability between sectors. The rise substitutability within sector leads to the reallocation of the output toward the most productive firms in the sectors because the household tends to buy the cheapest product. The firms’ R&D intensity increases because the gap between pre and post-innovation rent raises since the most productive firms have a higher market share. This feature is confirmed by Figure 33 that shows that the leaders’ output share raises as the substitutability within sector increases. The rise of competition within sector, such as the reduction of substitutability between sectors, is able to explain the trends of the growth of the R&D intensity and the the dispersion of firms’ size that the U.S. economy has been experiencing in the last two decades.

Regarding the intensity defensive practices, Figure 34 shows that the rise of the competition within sector, in contrast to the fall of substitutability between sectors, does not have a positive monotonic effect on defensive inten-
sity and it cannot quantitatively explain the growth of the pervasiveness of firms’ defensive behavior. The reason is twofold. First the rise of the substitutability has a direct and positive effect on the defensive intensity because the reduction of profits of the leaders due the catch-up is higher. However, the indirect effect of the greater market competition is that it reduces the probability of catch-up faced by leaders because the total R&D produced by followers falls due to the diminution of the number of followers per sector.

Differently from the fall of substitutability between sectors, the competition within sector does not have a positive and monotonic effect on value-weighted markups (Figure 35). The indirect effect of the greater market competition that leads to the fall of entry and the rise of concentration is most of the times overwhelmed by the direct effect that reduces the elasticity of markups with respect to size. Moreover, the rise of the elasticity of substitution within sector leads to a sharp decrease of the average markup in contrast to the mild growth that the U.S. experienced.

To conclude, this exercise of reverse engineering allows to shed the light on the possible structural changes that the U.S. economy may have experienced that can jointly explain the macroeconomic trends of R&D intensity, large firms’ size, pervasiveness of defensive practices and markups. The rise of competition within sector, such as the increase of the monopolistic markups, can justify the both rise of productivity R&D intensity and of the output share of the most productive firms in the sectors. However, the rise of substitutability within sector can not explain the dynamic of the defensive behavior and markups.

8 Conclusion

In this paper I study the firm-level and macroeconomic implication of firms’ defensive behavior through the lens of a general-equilibrium model with heterogeneous sectors and firms, featuring technology adoption with two types of R&D, productivity improving and defensive. I show that cracking down on defensive behaviour is not productivity enhancing, when the model is calibrated to the 2015 U.S. economy that is characterized by the skewed markup distribution. When the model is calibrated to the 1980 U.S. economy, in contrast, aggregate productivity increases by cracking down on defensive behavior of firms, with the markup distribution being less skewed. I found that product substitutability plays a crucial role in yielding this ambiguity, together its ability to reproduce the empirically consistent markup distributions at two different time points.

Imposing restrictions on firms’ ability to control their dominant position improves the technology adoption and knowledge spillover, allowing more laggard firms to catch-up and compete against frontier firms. This creates more sectors that are characterized by a neck-to-neck at the technological frontier, incentivizing them to innovate to escape competition. On the other hand, more competition implies that firms’ ability to appropriate the profits generated by innovation is limited, which in turn discourages firms to develop new products. The Schumpeterian effect dominates the escape-competition effect in a model that is calibrated to the 2015 U.S. economy, as compared to a model that is calibrated to the 1980 U.S. economy, where the Schumpeterian effect is not quantitatively important and thus tackling the production of defensive practices leads to the increase of welfare and aggregate productivity.
Furthermore, I found that the rise of the monopolistic markups, necessary to have an empirically consistent markups distribution, increases the incentives of the leaders to maintain their relative advantage toward the direct competitors within sectors, and consequently, it spurs the production of defensive practices, thereby reducing the incentive of leaders to invest in productivity improving R&D. The model shows that the presence of firms’ defensive behavior amplifies the effects of the fall of substitutability on the rise of market power and dispersion of markups and firms’ size distributions.

Lastly I compare the macroeconomic effect of the rise of product substitutability within sectors with the effects of fall of the substitutability between sectors to understand whether the Superstar firms’ Theory could explain the trends of the last two decades of the U.S. economy in R&D and defensive intensity and in the dynamic of markups. While the rise of the competition within sector, such as the the reduction of the substitutability between sectors, can justify the both rises of R&D intensity and the output share of the most productive firms, in contrast to fall of the elasticity of substitution between sectors, it can not explain the dynamic of the defensive behavior and markups.

The paper shows that the growth of the production of firms’ defensive practices may not due the lack of competition law enforcement by the authorities but it could simple reflect the structural change of the rise of the monopolistic markups and, consequently, of the benefit of the economy from production specialization. Under this framework, competition authorities that vigorously tackle the firms’ defensive behavior harm the economy.

To conclude the model can be easily extended to study the effects of firms’ defensive behavior on the business cycle fluctuations and its resulting policy prescription.
References


Tables

Table 5: Model correlations at firm level: low $\eta$

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</tr>
<tr>
<td></td>
<td></td>
<td>Calibration</td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>-0.26</td>
<td></td>
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</tr>
<tr>
<td>log(Share herd), log(Herfindahl)</td>
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<td>-0.06</td>
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</table>

Note: The table shows the correlation at firm level of the Benchmark economy.

Table 6: Gdp share of firms by size

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<th>High Calibration</th>
<th>High Calibration</th>
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<td>Defensive</td>
<td>No defensive</td>
</tr>
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<td>0.39</td>
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</tr>
<tr>
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<td>0.48</td>
<td>0.37</td>
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<tr>
<td>150%</td>
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<td>0.47</td>
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</table>

Note: The table shows the gdp shares of firms by firms’ size. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. Within each block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.

Table 7: Leaders’ persistence by size

<table>
<thead>
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<th>Benchmark Calibration</th>
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<th>High Calibration</th>
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<td>1.64</td>
<td>2.90</td>
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Note: The table shows the probability of staying leader within five years among leaders by size. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. Within each block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.

Table 8: Shares of aggregate output by firms’ productivity

<table>
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<th>Benchmark Calibration</th>
<th>High Calibration</th>
<th>High Calibration</th>
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<td>0.48</td>
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Note: The table compares the shares of the aggregate output by firms’ productivity. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. Within each block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.
Table 9: Shares of leaders’ total sales by leaders’ productivity

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<tr>
<th>Model</th>
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<th>High ε Calibration</th>
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<tr>
<td></td>
<td>μ</td>
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</tr>
<tr>
<td></td>
<td>σ</td>
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</tr>
<tr>
<td></td>
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<tr>
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</table>

Note: The table compares the shares of the leaders’ total sales by leaders’ productivity. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. Within each block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.

Table 10: Leaders’ sale shares

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<td>Sector</td>
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<tr>
<td></td>
<td>β</td>
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</table>

Note: The table compares the average share of output produced by a leaders among firms that belong to sectors with the same leader’s productivity. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. * Sectors with both leaders and followers * include only sectors where the number of followers exceeds 0 in the computation. Within each sub-block, the first column refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.
The table compares the value-weighted and average markups among firms that belong to sectors with the same leader's productivity. *Sectors with both leaders and followers* include only sectors where the number of followers exceeds 0 in the computation. Within each sub-block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.

Table 11: Value-weighted and Average Markups: Benchmark Economy

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<th>Sectors with both leaders and followers</th>
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<td>Defensive</td>
<td>No defensive</td>
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<td>1.45</td>
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</table>

Note: The table compares the value-weighted and average markups among firms that belong to sectors with the same leader's productivity. *Sectors with both leaders and followers* include only sectors where the number of followers exceeds 0 in the computation. Within each sub-block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.

Table 12: Percentage of sectors without followers

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<td>$\gamma$</td>
<td>23.15%</td>
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<td>$\delta$</td>
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<td>29.41%</td>
</tr>
<tr>
<td>$T$</td>
<td>48.72%</td>
<td>23.72%</td>
</tr>
<tr>
<td>$R$</td>
<td>35.30%</td>
<td>21.96%</td>
</tr>
<tr>
<td>$c_{12}$</td>
<td>27.70%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{21}$</td>
<td>20.08%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{13}$</td>
<td>17.58%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{23}$</td>
<td>10.00%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{34}$</td>
<td>4.54%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{35}$</td>
<td>3.90%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{45}$</td>
<td>3.90%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{16}$</td>
<td>3.90%</td>
<td>14.77%</td>
</tr>
<tr>
<td>$c_{26}$</td>
<td>3.90%</td>
<td>14.77%</td>
</tr>
</tbody>
</table>

Note: The table compares the percentage of sectors without followers among sectors with the same leader’s productivity between the economy with and without defensive behavior. The first block refers to the model with the benchmark calibration, while the second block refers to the calibrated model with high substitutability between sectors. Within each block, the first column on the left refers to the economy in which leaders can produce defensive practices. The second column refers to the economy without defensive behavior.
Table 13: Value-weighted markups decomposition: Benchmark Calibration

<table>
<thead>
<tr>
<th></th>
<th>Benchmark behavior</th>
<th>No defensive behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Value-weighted</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.05</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.04</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Table 14: Value-weighted and Average Markups: High η Calibration

<table>
<thead>
<tr>
<th></th>
<th>Sector with both leaders and followers</th>
<th>All sectors</th>
<th>Sector with both leaders and followers</th>
<th>All sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Defenders</td>
<td>No defences</td>
<td>Defenders</td>
<td>No defences</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1.55</td>
<td>1.60</td>
<td>1.55</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.48</td>
<td>1.50</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>1.42</td>
<td>1.43</td>
<td>1.42</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>1.47</td>
<td>1.49</td>
<td>1.47</td>
</tr>
</tbody>
</table>

Note: The table compares the value-weighted and average markups among firms that belong to sectors with the same leader’s productivity. The second column refers to the economy in which leaders can produce defensive R&D. The second column refers to the economy without defensive behavior.
Figures

Figure 3: Relationship between sector’s R&D intensity and Herfindahl Index

Note: The figure shows the scatter plot of the sector population of the benchmark economy based on the levels of concentration measured by Herfindahl index and on the sector R&D intensity computed as the expected sector’s total R&D expenditure over sector’s total revenues. The expected total R&D expenditure includes also the expenditures in defensive practices. The red line represents the estimated quadratic regression of sector’s R&D expenditure on log-Herfindahl index.

Figure 4: Leader’s productivity improving R&D policy as function of technology gap

Note: The figures show the leader’s productivity improving R&D choice of the benchmark economy as function of its productivity in sectors with $n^I = 2$, $n^F = 2$ and fixed the followers’ productivity $\epsilon^F = \epsilon^H$. The left figure represents the R&D intensity calculated as the percentage of the expenditures in the revenues. The right figure shows the choice of the leader regarding units of productivity improving R&D produced.
Figure 5: Leader’s productivity improving R&D policy as function of the number of leaders

Note: The figures show the leader’s productivity improving R&D choice of the benchmark economy as function of the number of leaders in sectors with n\(f = 2\), \(\varepsilon f = \varepsilon_2\) and \(\varepsilon l = \varepsilon_3\). The first figure on the left shows the leaders’ R&D intensity calculated as the percentage of the expenditures in the revenues. The second figure shows the choice of the leader regarding units of productivity improving R&D produced. The figure on the right shows the total units of productivity improving R&D produced by leaders in the sector.

Figure 6: Follower’s R&D policy as function of technology gap

Note: The figures show the follower’s R&D choice of the benchmark economy as function of leader’s productivity in sectors with n\(l = 2\), n\(f = 2\) and fixed the followers’ productivity \(\varepsilon f = \varepsilon_2\). The left figure represents the R&D intensity calculated as the percentage of the expenditures in the revenues. The right figure shows the R&D choice of the follower regarding units of R&D produced.
Figure 7: Follower’s R&D policy as function of the number of leaders

Note: The figures show the follower’s R&D choice of the benchmark economy as function of the number of leaders in sectors with $n^f = 2$, $\varepsilon^f = \varepsilon_2$ and $\varepsilon^l = \varepsilon_3$. The first figure on the left shows the follower’s R&D intensity calculated as the percentage of the expenditures in the revenues. The second figure shows the choice of the follower in terms of units of R&D produced.

Figure 8: Follower’s R&D policy as function of the number of followers

Note: The figures show the follower’s R&D choice of the benchmark economy as function of the number of followers in sectors with $n^f = 2$, $\varepsilon^f = \varepsilon_2$ and $\varepsilon^l = \varepsilon_3$. The first figure on the left shows the follower’s R&D intensity calculated as the percentage of the expenditures in the revenues. The second figure shows the choice of the follower regarding units of R&D produced. The figure on the right shows the total units of R&D produced by followers in the sector.
Figure 9: Leader’s defensive R&D policy as function of the technology gap

Note: The figures show the leader’s defensive R&D choice of the benchmark economy as function of its productivity in sectors with $\eta^l = 2$, $\eta^f = 2$ and fixed the followers’ productivity $\varepsilon^f = \varepsilon_2$. The left figure represents the defensive R&D intensity calculated as the percentage of the expenditures in the revenues. The right figure shows the choice of the leader regarding units of defensive R&D produced.

Figure 10: Leader’s defensive R&D policy as function of the number of leaders

Note: The figures show the leader’s defensive R&D choice of the benchmark economy as function of the number of leaders in sectors with $\eta^f = 2$, $\varepsilon^f = \varepsilon_2$ and $\varepsilon^l = \varepsilon_3$. The left figure represents the defensive R&D intensity calculated as the percentage of the expenditures in the revenues. The second figure shows the choice of the leader regarding units of defensive R&D produced. The figure on the right shows the total units of defensive R&D produced.
Figure 11: Leader’s defensive R&D policy as function of the number of followers

Note: The figures show the leader’s defensive R&D choice of the benchmark economy as function of the number of followers in sectors with $n_l = 2$, $\varepsilon_f = \varepsilon_2$ and $\varepsilon_l = \varepsilon_3$. The left figure represents the defensive R&D intensity calculated as the percentage of the expenditures in the revenues. The right figure shows the choice of the leader regarding units of defensive R&D produced.

Figure 12: Follower’s R&D as function of technology gap

Note: The figures show the average choice of R&D of the follower of the benchmark economy as function of the the technology gap of the sectors. The first figure on the left shows the average R&D intensity among followers that belong to the sectors with the same combination of productivities of leaders and followers. The second figure shows the average R&D units of followers that belong to sectors with the same combination of productivities of leaders and followers.
Figure 13: Leader’s productivity improving R&D as function of technology gap

Note: The figures show the choice of productivity improving R&D of the leader of the benchmark economy as function of the technology gap of the sectors. The first figure on the left shows the average productivity improving R&D intensity among leaders that belong to sectors with the same combination of productivities of leaders and followers. The second figure shows the average productivity improving R&D units chosen among leaders that belong to sectors with the same combination of productivities of the leaders and followers. The figure on the right shows the average total productivity improving R&D units chosen leaders in sectors with the same combination of productivities of leaders and followers.

Figure 14: Concentration, number of leaders and entrants as function of technology gap

Note: The figures show the number of firms as function of the technology gap of the sectors. The first figure on the left shows the average number of firms in sectors with the same combination of productivities of leaders and followers. The second figure shows the average number of leaders in sectors with the same combination of productivities of leaders and followers. The figure on the right shows the average number of entrants in sectors with the same combination of productivities of leaders and followers. The figures refer to the benchmark economy.
Figure 15: Leader’s defensive R&D as function of technology gap

![Defensive Intensity](image1)

![Units of Defensive](image2)

Note: The figures show the leader’s defensive R&D choices of the benchmark economy as function of the technology gap of the sectors. The first figure on the left shows the average defensive R&D intensity among leaders that belong to sectors with the same combination of productivities of leaders and followers. The second figure shows the average defensive R&D units chosen by leaders that belong to sectors with the same combination of productivities of leaders and followers.

Figure 16: Morning game as function of the technology gap

![Total R&D Units of Followers](image3)

![Total Units of Defensive](image4)

![Probability of Catch-Up](image5)

Note: The first figure on the left shows the average followers’ total R&D units among sectors with the same combination of productivities of leaders and followers. The second figure shows the average leaders’ total defensive R&D units among sectors with the same combination of productivities of leaders and followers. The figure on the right shows the average probability that a follower catches up among sectors with the same combination of productivities of leaders and followers. The figures refer to the benchmark economy.
Figure 17: Firms’ size distributions

Note: The figure shows the firms’ sale size distributions for the benchmark economy in blue and for the economy without defensive behavior in red, obtained by the simulations of the models.

Figure 18: Direct and Indirect effect of the defensive practice for the leaders

Note: The figures show the leader’s productivity improving R&D choice of the model with benchmark calibration as function of the technology gap of the sectors. The first figure on the left compares the leader’s productivity improving R&D intensity as function of the technology gap in sectors with $n^I = 2$, $n^L = 2$ and $s^I = e_2$ between models with and without defensive practice. The second figure compares the leader’s productivity improving R&D choice as function of the technology gap in sectors with $n^I = 2$, $n^L = 2$ and $s^I = e_2$ between models with and without defensive practice. The third figure shows the total leaders’ productivity improving R&D produced as function of the technology gap in sectors with $n^I = 2$, $s^I = e_2$ and $s^L = e_3$ in model with and without defensive practice.
Figure 19: Comparison of the followers’ R&D

Note: The first figure on the left overlaps the average R&D intensity of the economies with and without defensive behavior among followers that belong to sectors with the same combination of productivities of leaders and followers. The second figure overlaps the average R&D units of economies with and without defensive behavior among followers that belong to sectors with the same combination of productivities of leaders and followers. The figure on the right overlaps the mass of sectors in the morning of economies with and without defensive behavior for each possible combination of productivities of leaders and followers. The figures refer to the model with the benchmark calibration.

Figure 20: Comparison of distribution, leaders and entrants

Note: The first figure on the left overlaps the mass of sectors of the economies with and without defensive behavior with the same combination of productivities of leaders and followers. The second figure overlaps the average number of leaders of economies with and without defensive behavior among sectors characterised by the same combination of productivities of leaders and followers. The figure on the right overlaps the average number of entrants of economies with and without defensive behavior among sectors characterised by the same combination of productivities of leaders and followers. The figures refer to the model with the benchmark calibration.
Figure 21: Comparison of the followers’ innovation intensity

Note: The first figure on the left overlaps the average total followers’ R&D units of the economies with and without defensive behavior calculated among sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps the average total number of followers in the morning of the economies with and without defensive behavior calculated among sectors characterised by the same combination of productivities of leaders and followers. The third figure overlaps the average probability that a follower catches up of the economies with and without defensive behavior calculated among sectors characterised by the same combination of productivities of leaders and followers.

Figure 22: Comparison of the leader’ productivity improving R&D

Note: The first figure on the left overlaps the average productivity improving R&D intensity of the economies with and without defensive behavior calculated among leaders that belong to the sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps the average productivity improving R&D units of the economies with and without defensive behavior calculated among leaders that belong to the sectors characterised by the same combination of productivities of leaders and followers. The third figure overlaps the mass of sectors in the afternoon of the economies with and without defensive behavior for each possible combination of productivities of leaders and followers. The figures refer to the model with the benchmark calibration.
Figure 23: Firms' size distributions

Note: The figure shows the firms' sale size distributions of the economies with, in blue, and without, in red, defensive behavior. The figure refers to the model with the high $\eta$ calibration.

Figure 24: Comparison of the follower's R&D

Note: The first figure on the left overlaps the average R&D intensity of the economies with low and high $\eta$ calculated among followers that belong to sectors characterized by the same combination of productivities of leaders and followers. The second figure overlaps the average R&D units of the economies with low and high $\eta$ calculated among followers that belong to sectors characterized by the same combination of productivities of leaders and followers. The figure on the right overlaps the mass of sectors in the morning of the economies with low and high $\eta$ for each possible combination of productivities of leaders and followers.
Figure 25: Comparison of distribution, leaders and entrants

Note: The first figure on the left overlaps the mass of sectors of the economies with low and high $\eta$ calculated among followers that belong to sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps the average number of leaders of economies with low and high $\eta$ calculated among sectors characterised by the same combination of productivities of leaders and followers. The figure on the right overlaps the average number of entrants of economies with low and high $\eta$ calculated among sectors characterised by the same combination of productivities of leaders and followers.

Figure 26: Comparison of the defensive R&D

Note: The first figure on the left overlaps the average defensive R&D intensity of the economies with low and high $\eta$ calculated among leaders that belong to sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps the average defensive R&D units of the economies with low and high $\eta$ calculated among leaders that belong to sectors characterised by the same combination of productivities of leaders and followers. The third figure overlaps the average total defensive R&D units of the economies with low and high $\eta$ calculated among sectors characterised by the same combination of productivities of leaders and followers.
Figure 27: Comparison of the followers’ innovation intensity

Note: The first figure on the left overlaps the average total units followers’ R&D of the economies with low and high $\eta$ among followers that belong to sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps average probability of catch-up of the economies with low and high $\eta$ calculated among sectors characterised by the same combination of productivities of leaders and followers.

Figure 28: Comparison of the leader’ productivity improving R&D

Note: The first figure on the left overlaps the average productivity improving R&D intensity of the economies with low and high $\eta$ calculated among leaders that belong to sectors characterised by the same combination of productivities of leaders and followers. The second figure overlaps the average productivity improving R&D units of the economies with low and high $\eta$ calculated among leaders that belong to sectors characterised by the same combination of productivities of leaders and followers. The figure on the right overlaps the average total leaders’ productivity improving R&D units of the economies with low and high $\eta$ calculated among sectors characterised by the same combination of productivities of leaders and followers.
Figure 29: Comparison of the followers’ R&D

Note: The first figure on the left overlaps the average R&D intensity of the economies with and without defensive behavior calculated among followers that belong to sectors characterized by the same combination of productivities of leaders and followers. The second figure overlaps the average R&D units of the economies with and without defensive behavior calculated among followers that belong to sectors characterized by the same combination of productivities of leaders and followers. The third figure overlaps the mass of sectors characterized by the same productivities of leaders and followers in the economy with and without defensive behavior. The third figure overlaps the average total followers’ R&D units of the economies with and without defensive behavior among sectors productivities of leaders and followers the same combination of productivities of leaders and followers. The figures refer to the model with the high $\eta$ calibration.

Figure 30: Comparison of the leader’s productivity improving R&D

Note: The first figure on the left overlaps the average productivity improving leaders’ R&D intensity of the economies with and without defensive behavior calculated among that belong to sectors characterized by the same combination of productivities of leaders and followers. The second figure overlaps the average productivity improving R&D units of the economies with and without defensive behavior calculated among leaders that belong to sectors characterized by the same combination of productivities of leaders and followers. The third figure overlaps the average total leaders’ productivity improving R&D units of the economies with and without defensive behavior calculated among the sectors characterized by the same combination of productivities of leaders and followers. The figures refer to the model with the high $\eta$ calibration.
Figure 31: Comparison of distributions and number of leaders and entrants

Note: The first figure on the left overlaps the mass of sectors characterized by the same combination of productivities of the economies with and without defensive behavior. The second figure overlaps the average number of leaders of economies with and without defensive behavior calculated among sectors characterized by the same combination of productivities of leaders and followers. The figure on the right overlaps the average number of entrants of economies with and without defensive behavior calculated among sectors characterized by the same combination of productivities of leaders and followers. The figures refer to the model with the high $\eta$ calibration.

Figure 32: R&D intensity with different substitutability between and within sectors

Note: The first figure on the left shows the different R&D intensities of economies characterized by different levels of substitutability between sectors. The second figure shows the different R&D intensities of economies characterized by different levels of substitutability within sectors.
Figure 33: Leaders’ output share with different substitutability between and within sectors

Note: The first figure on the left shows the different leaders’ output shares of economies characterized by different levels of substitutability between sectors. The second figure shows the different leaders’ output shares of economies characterized by different levels of substitutability within sectors.

Figure 34: Defensive intensity with different substitutability between and within sectors

Note: The first figure on the left shows the different defensive intensities of economies characterized by different levels of substitutability between sectors. The second figure shows the different defensive intensities of economies characterized by different levels of substitutability within sectors.
Figure 35: Markups with different substitutability between and within sectors

Note: The first above figure on the left shows the different value-weighted markups of economies characterized by different levels of substitutability between sectors. The second above figure shows the different average markups of economies characterized by different levels of substitutability between sectors. The first below figure on the left shows the different value-weighted markups of economies characterized by different levels of substitutability within sectors. The second below figure shows the different average markups of economies characterized by different levels of substitutability within sectors.
A Appendix A

A.1 Proposition 1

I can now describe the optimal choice of the defensive practices chosen by the leaders. In the case where $V_2^f(e', e', n'_1, n'_f) - V_2^f(e', e', n'_1 + 1, n'_f - 1) < 0$, the unique symmetric equilibrium is $x_1^* = 0$.

Conversely, if $V_2^f(e', e', n'_1, n'_f) - V_2^f(e', e', n'_1 + 1, n'_f - 1) > 0$, The first and second order conditions of the optimization problem

\[
\frac{\partial V_2^f(e', e', n'_1, n'_f)}{\partial x_1^f} = -w + \frac{X^f}{X^f + R^f} \left[ \frac{n'_1}{n'_f} \frac{(n'_1 - 1)}{X^f + R^f} \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) \right]
\]

\[
\frac{\partial^2 V_2^f(e', e', n'_1, n'_f)}{\partial x_1^f \partial x_1^f} = -w \left[ \frac{X^f}{X^f + R^f} \right]^2 \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) < 0
\]

Rearranging I derive the equation that describes the symmetric equilibria:

\[
x_1^f = f(x_1^f, X^f) = \frac{1}{n'_f} \sqrt{\frac{X^f}{X^f + R^f} \left[ \frac{n'_1}{n'_f} \frac{(n'_1 - 1)}{X^f + R^f} \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) \right] - \frac{R^f}{n'_f}}
\]

Given $x_1^f$ describes a self-map where:

- $\lim_{x_1^f \to -\infty} f(x_1^f, X^f) = +\infty$
- $\lim_{x_1^f \to +\infty} f(x_1^f, X^f) = -\frac{R^f}{n'_f}$
- $\frac{\partial f(x_1^f, X^f)}{\partial x_1^f} < 0 \quad \forall x_1^f \in \mathbb{R}_+$

So there must exist a unique $x_1^* = f(x_1^{*f}, X^f)$.

Moreover, I can verify that

\[
\frac{\partial f(x_1^f, X^f)}{\partial x_1^f} > 0 \quad \forall x_1^f \in \mathbb{R}_+
\]

that implies:

\[
\frac{\partial x_1^*}{\partial X^f} > 0 \quad \forall X^f \in \mathbb{R}_+
\]

A.2 Proposition 2

The first and second order conditions of the optimization problem

\[
\frac{\partial V_2^f(e', e', n'_1, n'_f)}{\partial x_1^f} = -w + \frac{X^f}{X^f + R^f} \left[ \frac{n'_1}{n'_f} \frac{(n'_1 - 1)}{X^f + R^f} \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) \right] = 0
\]

\[
\frac{\partial^2 V_2^f(e', e', n'_1, n'_f)}{\partial x_1^f \partial x_1^f} = -w \left[ \frac{X^f}{X^f + R^f} \right]^2 \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) < 0
\]

where $\Delta \tilde{V}_2^f(e', e', n'_1, n'_f) = [V_2^f(e', e', n'_1 + 1, n'_f - 1) - V_2^f(e', e', n'_1, n'_f)]$ is the difference between the value of winning and the value when no follower succeeds, and

$\Delta \tilde{V}_2^f(e', e', n'_1, n'_f) = [V_2^f(e', e', n'_1 + 1, n'_f - 1) - V_2^f(e', e', n'_1 + 1, n'_f - 1)]$ is the difference between the expected value of winning and the expected value when another followers wins the contest.

Rearranging I derive the equation that describes the symmetric equilibria:

\[
x_1^f = q(x_1^f, X^f) = \frac{1}{n'_f} \sqrt{\frac{X^f}{X^f + R^f} \left[ \frac{n'_1}{n'_f} \frac{(n'_1 - 1)}{X^f + R^f} \Delta \tilde{V}_2^f(e', e', n'_1, n'_f) \right] - \frac{R^f}{n'_f}}
\]

Given $X_1^f$ describes a self-map where:

- $\lim_{x_1^f \to -\infty} q(x_1^f, X_1^f) = +\infty$
- $\lim_{x_1^f \to +\infty} q(x_1^f, X_1^f) = 1$
- $\frac{\partial q(x_1^f, x_1^f)}{\partial x_1^f} < 0 \quad \forall x_1^f \in \mathbb{R}_+$
So there must exist a unique $x_{1}^{*}$ such that $x_{1}^{*} = f(x_{1}^{*}, X_{1})$. The equilibrium quantities of R&D chosen by followers, $x_{1}^{*}$, is increasing $\Delta \tilde{V}_{1}(e', \epsilon, n', n')$ and $\Delta \tilde{V}_{1}(e', e', n', n')$.

Moreover, I can verify that
\[
\frac{\partial q(x_{1}, X_{1})}{\partial X_{1}} < 0 \quad \forall X_{1} \in \mathbb{R}_{+}
\]
that implies:
\[
\frac{\partial x_{1}^{*}}{\partial X_{1}} < 0 \quad \forall X_{1} \in \mathbb{R}_{+}
\]

### A.3 Proposition 3

Let $f_{1}^*: x' \rightarrow x_{1}^{*}$ and $q_{1}^*: X_{1} \rightarrow x_{1}^{*}$, by [32] and [36]

- $\frac{\partial f_{1}^{*}(x')}{\partial x} > 0 \quad \forall x' \in \mathbb{R}_{+}$
- $\frac{\partial q_{1}^{*}(x_{1})}{\partial x_{1}} < 0 \quad \forall x_{1} \in \mathbb{R}_{+}$

then it implies that there must exist a unique $(x_{1}^{*}, x_{1}^{*})$ such that:

- $x_{1}^{*} = f_{1}^{*}(q_{1}^{*}(x_{1}^{*}))$
- $x_{1}^{*} = q_{1}^{*}(f_{1}^{*}(x_{1}^{*}))$

### A.4 Proposition 4

Let $\Delta \tilde{V}_{1}(e', \epsilon, n', n') = [\hat{E}[V_{1}(e', \epsilon, n', n') - V_{1}(e', \epsilon, n', n')]$, which is the difference between the expected value of winning the contests and the value when no leader succeeds. For $\Delta \tilde{V}_{1}(e', \epsilon, n', n') < 0$, the unique symmetric equilibrium is $x_{1}^{*} = 0$.

Conversely, if $\Delta \tilde{V}_{1}(e', \epsilon, n', n') > 0$, I take the first and second order conditions of the recursive optimization problem
\[
\frac{\partial^{2} V_{2}(e', \epsilon, n', n')}{\partial x_{1}^{2}} = -w_{x_{2}} + \frac{[R_{1} \Delta \tilde{V}_{1}(e', \epsilon, n', n') + (X_{1} - x_{1}) \Delta \tilde{V}_{1}(e', \epsilon, n', n')]}{(X_{1} + R_{1})^{2}} = 0
\]
\[
\frac{\partial^{2} V_{2}(e', \epsilon, n', n')}{\partial x_{1}^{2}} = -w - 2 \frac{[R_{1} \Delta \tilde{V}_{1}(e', \epsilon, n', n') + (X_{1} - x_{1}) \Delta \tilde{V}_{1}(e', \epsilon, n', n')]}{(X_{1} + R_{1})^{3}} < 0
\]

where $\Delta \tilde{V}_{1}(e', \epsilon, n', n') = [\hat{E}[V_{1}(e', \epsilon, n', n') - V_{1}(e', \epsilon, n', n')]$ is the difference between the expected value of winning contest and the expected value if another leader wins.

Rearranging [31] I derive the equation that describes the symmetric equilibria:
\[
x_{2} = \omega(x_{2}) = 1 \frac{R_{1}}{w x_{1}} \Delta \tilde{V}_{1}(e', \epsilon, n', n') + \frac{(n' - 1)}{w} \Delta \tilde{V}_{1}(e', \epsilon, n', n') - \frac{R_{1}}{n' t}
\]

[31] represents a self-map where:

- $\lim_{x_{1} \to 0} \omega(x_{1}) = +\infty$
- $\lim_{x_{1} \to \infty} \omega(x_{1}) = \sqrt{\frac{(n' - 1)}{w} \Delta \tilde{V}_{1}(e', \epsilon, n', n') - \frac{R_{1}}{n'}}$
- $\frac{\partial \omega(x_{1})}{\partial x_{2}} < 0 \quad \forall x_{1} \in \mathbb{R}_{+}$

So, also in this game, there must exist a unique $x_{2}^{*}$ such that $x_{2}^{*} = \omega(x_{2}^{*})$. 