Defensive strategies in the quality ladders

Ivan Ledezma

Ivan Ledezma. Defensive strategies in the quality ladders. 2008. halshs-00586709

WORKING PAPER N° 2008 - 29

Defensive strategies in the quality ladders

Ivan Ledezma

JEL Codes: L1, D2, O3
Keywords: innovative leaders, quality ladders, R&D, regulation, industry-level data

Defensive Strategies in the Quality Ladders

Ivan Ledezma [*,†]

October, 2009

Abstract

This paper analyses the potentially defensive behaviour of patent race winners and its effect on aggregate R&D effort. It proposes a quality-ladders model that endogenously determines leader's technology advantages and who innovates (the leader firm or its competitors). Product market regulation can have either a positive or a negative effect on R&D intensity. It can be negatively associated to aggregate innovative effort in highly deregulated economies. In more regulated ones, where deterring strategies are constrained, it provides incentives to innovate. These predictions are consistent with data on manufacturing industries for 14 OECD countries during the period 1987-2003.

Keywords: industry-level data, innovative leaders, quality ladders, R&D, regulation.

JEL Code: L1, D2, O3

---

[*] I am grateful to Bruno Amable, Philippe Askenazy, José Miguel Benavente and Dominique Guellec for their helpful and detailed comments. I have also benefited from the reading and suggestions of Maria Bas and Elvire Guillaud. All remaining errors, of course, are my own.

[†] Centre d'Economie de la Sorbonne & Université Paris-Dauphine, LEDa-DIAL, 75775 Paris Cedex 16. Tel. 33 (0)1 44 05 42 67. Email: ivan.ledezma@dauphine.fr

1 Introduction

Several empircal studies based on R&D surveys show that firms protect the value of their innovations using multiple strategies (Levin et al., 1987; Nelson and Walsh, 2000; Cohen et al., 2002). It is argued in this paper that this multiplicity is important to understand the effect of competition on R&D incentives. If firms have several alternatives to keep their profits, potential competition may not necessarily act as a slack-reducing device. Rather than neutral innovative behaviour, the thread of competition can in practice trigger defensive reactions of incumbents. They can construct different types of strategic barriers aiming at protecting their business position from the risk of loosing future innovation contests.[1] The aim of this paper is to analyse the impact of this defensive behaviour on aggregate R&D effort and market structure. Particular attention is devoted to the way in which market regulation can influence aggregate R&D effort.

The paper first proposes a quality ladder model where R&D races are structured by strategic barriers, the cost of which is assumed to be positively correlated with regulation. Within a Stackelberg game of the kind presented in Barro and Sala-i-Martin (2004), an important contribution of the model is that the new successful innovator strategically acquires R&D cost advantages vis-à-vis his competitors. These advantages allow him to further innovate. The main result is that regulation can have either a positive or a negative effect on R&D intensity. It all depends on the pre-existing regulation level. In more liberal environments the equilibrium is characterised by a long-life innovative monopolist. Here an increase in regulation will be detrimental to innovation because it distorts the innovative activity of the leader. However, after attaining a certain threshold of regulation, the economy experiments Schumpeterian replacement. In this case, regulatory provisions can positively influence aggregate R&D effort since they reduce the deterring effect on outsiders. Because of Schumpeterian incentives stemming from the technology gap between leaders and followers, this positive impact is all the more important that the size of innovation is bigger.

The starting point to understand these results is to conceive regulation as a device constraining the set of available strategies, namely those leading to entry deterrence in R&D. In the model this kind of strategies are illustrated by the choice made by the leading firm regarding the direction of the innovative path. The idea is that innovation is not only a purely product/process

---

[1] Consistent with R&D surveys findings, Crépon and Duguet (1997) show evidence of negative R&D externalities among French manufacturing firms in narrowly defined industries, a result interpreted by the authors as the outcome of competitors' rivalry.

improvement but a strategically "biased" one. Regulation can (de facto) limit the possibilities of technological manipulation (think in certifications, anti-bundling, quality controls, certifications, licensing, etc). An important point is that even some usually-called market barriers can fit this definition. Theoretically speaking, all that is needed is a rule that directly or inderectly sets the boundaries of the business process and product containing the state-of-the-art knowledge. This is why the empirical excercise deliberatly uses indicators constructed to measure market barriers.[2]

Model's predictions are tested using industry-level data of OECD countries for the period 1987-2003. Several indicators of regulation provided by the OECD appear positively correlated with R&D intensity in high-tech industries, precisely those industries where the size of innovation usually yields big innovative jumps. Consistent with the model, once the sample is split to investigate a differentiated effect of regulation on R&D intensity, a negative correlation shows-up in highly deregulated environments. The opposite is observed in more coordinated ones.

These empirical results are themselves new interesting evidence that the paper helps to explain. As surprising as it may be, they are broadly consistent with previous studies at the industry level. Most of them, explore the link between regulation and economic performance by relying on OECD regulation indicators (as in this work). Nicoletti and Scarpetta (2003) report a positive interaction between product market regulation and the proximity to the technology frontier in a model explaining multifactor productivity growth. While the authors interpret their finding as a negative effect of regulation on the catching-up process, it also implies that the impact of regulation on productivity growth positively increases with the proximity to the frontier. Similarly, Amable et al. (2009) find no evidence of a negative effect of regulation on innovative performance close to the technology frontier. After several robustness checks, what remains is that the marginal effect of regulation on innovation tends to be positive at the leading edge.[3] Inklaar et al. (2007) analyse several sources of multifactor productivity growth in service sectors. Excepting telecommunications, their results fail to show a robust negative effect of market barriers indicators on productivity growth. On the other hand, Arnold et al. (2008)

---

[2] *The Economist* in the title of the printed article of May 1st 2008 reflects the non-trivial link between regulation and competition: "Oceans Apart: Europe still seems to have less faith than America in the ability of the free market to tame monopolies".

[3] These industry-level works contradict micro-level results found by Aghion et al. (2005) for a panel of UK firms using profitability-based measures of competition. The inverted-U shape pattern between competition and innovation, that underlies Aghion et al.'s (2005) claim, has also been empirically relativised at the micro-level by Tingvall and Poldahl (2006). A number of theoretical arguments, dealing with strategic behaviour, can be mentioned to explain the lack of clear-cut results on this matter (see for instance Etro 2007, Chapter 4; Tishler and Milstrein, 2009; Amable et al. 2009;)

do report that regulation induce a negative effect on firm productivity, but only in ICT-using industries. Among them, their sample considers several service sectors which are not present in the manufacturing sample used in this paper. Griffith et al. (2006) investigate the effect of the Single Market Programme (SMP) on R&D expenditure. Differently from the previously mentioned empirical works, the authors construct indirect indicators of market regulation through a step function that, basically speaking, seeks to measure the expected exposition to the SMP. Profitability effects of regulation are isolated following a two-step methodology. Results are that the liberalisation trend induced by the SMP is positively correlated with R&D investment. However, in line with the results presented in the present work, in several of R&D reduced-form regressions (i.e. including other chanels than profitability) and also in some of the robustness check TFP regression, the group of industries related to the catgeory of "high-tech public procurement" (including telecommunications equipment, office machinery and medical and surgical equipment) presents a significantly negative correlation, that is to say, a negative impact of *deregulation* on R&D and productivity.[4]

The theoretical explanation proposed by the paper brings some standard developments of industrial organisation (IO) into a quality-ladders growth setting. Whilst strategic entry deterrence and preemption in R&D races have been deeply analysed in IO works they have received much less attention in Schumpeterian growth models until recently.[5] Some exemples include explicitly defensive behaviour of incumbents such as the introduction of tacitness in the knowledge embodied in production techniques in order to prevent leapfrogging (Thoenig and Verdier, 2003) or the engagement in patent blocking, intelectual property disputes and the like to delay their replacement (Dinopoulos and Syropoulos, 2007). In such papers firms play simultaneously in a Nash-Cournot equilibrium and have symmetric technologies in R&D. These assumptions imply that Arrow replacement effect holds and leaders do not continue to innovate. There is however, convincing evidence about the active rôle of leaders in R&D (see for instance Chandler, 1990; Malerba et al., 1997). In the proposed model, the participation of the leader in R&D contests arises endogenously.

The circumstances under which the Arrow effect vanishes has also been addressed in early in-

---

[4] Other related evidence is that provided by macro-institutional literature emphasising the diversity of capitalism (Albert, 1991, Hall and Soskice, 2001; Amable, 2003). Different institutionals configurations are able to deliver economic performance. In some of them, market-based forces ensured by a deregulated environment are the key dynamic engine, in other it is rather institutional coordination and welfare state that are associated to economic performance. The evidence provided later is broadly compatible with this line of research.

[5] Bain (1949), Williamson, (1963), Salop (1977), Dasgupta et al. (1982), Gilbert and Newberry (1982) and Reinganum (1983) are some early exemples of IO works.

fluent models of patent races but only recently spanned into quality-ladders literature.[6] This define a special class of models able to reproduce innovative leaders. This can be done, for instance, thanks to the assumption of exogenous R&D advantages either within Nash-Cournot equilibriums and decreasing returns in R&D technology (Segerstrom and Zolnierek, 1999; Segerstrom, 2007) or within a Stackelberg type game (Etro, 2007 & 2008) that can be represented in a simple version with constant returns in R&D (Barro and Sala-i-Martin, 2004-Chapter 7). These works, however, consider innovation contests where the asymmetry betwen the R&D technology of the leader and that of the follower is exogenous. The explanation proposed here links these models with the above mentioned category by reproducing endogenous relative R&D advantages of leaders through defensive strategies. Introducing a stage in which R&D asymmetries can be acquired renders more sounding the first move advantage game.[7]

Similar strategic issues has been recently analysed by Grossman and Steger (2008). They show, that from the leader's point of view, the erection of entry barriers and R&D are complementary activities. Despite entry blocking, this behaviour can be conductive to positive growth effects when outsiders' R&D do not generate knowledge spillovers. Important differences exist between their model and the one presented in this paper: Cournot versus Bertrand competition here, deterministic innovation versus risky R&D investment here, a rather static entry barrier construction versus path dependency here (among others). This makes comparisons hard. Their results are, however, compatible with the equilibrium with permantent monopolist. Overall, what should be kept in mind is that, rather than render the analysis ambiguous, the richness of IO tools provides a highly selective level of robustness scrutiny. It is then not surprising to conclude that the relationship between competition and innovation remains an open question.

The rest of the paper is organised as follows. Section 2 presents the model and Section 3 the empirical findings. Finally, concluding remarks are presented in Section 4. In order to keep the exposition simple, most of technical developments is presented in appendix.

---

[6] For patent races works, see for instance the interesting discrepancies between Gilbert and Newberry (1982) and Reinganum (1983).

[7] An alternative line of argument is that of Denicolò (2001). If innovation is non-radical, the gap in the industry can be such that the leader may practice a monopolist price while the next competitive outsider engage in Bertrand competition with consequently lower incitations. As knowledge spillovers, specially in high-technology industries, may constrain the sustainable technology gap between firms, the explanation of R&D advantages is put forward in the present work. Even if small, these R&D cost advantages justify that the leader continuously invests in R&D (Klette and Griliches, 2000).

2 The model

For the sake of simplicity, the formal setting is based on a semi-endogenous quality-ladders model without scale effects. The basic setup is based on Li (2003) which generalises Segerstrom's (1998) framework. It considers imperfect inter-industry substitutability and remove steady state scale effects by assuming that, as quality improves, new discoveries need more R&D effort. At equilibrium the innovation rate will not depend on the size of labour allocated to R&D but on the rate of population growth.[8]

Section 2.1 begins presenting the rationale of the model, 2.2 follows with the basic setup of consumption and production. The core of the setting is then presented: the strategic use of private knowledge and capabilities (Sections 2.3 and 2.4) and the effects on aggregate R&D effort at equilibrium (Section 2.5).

2.1 The model in words

The model consists of two main ingredients: (i) an endogenous choice of technological bias and (ii) a Stackelberg type game in which the leader has the first mover advantage. Through a vectorial representation, the leader (i.e. the new succesful innovator) is assumed to chose its level of R&D investment but also the specific quality mix to be introduced into the market. By changing the latter, the new incumbent introduces a "technological bias" in the direction of the innovation path and obtains R&D cost advantages that are crucial in the Stackelberg game. Challengers are compelled to provide a new business solution in the context of several disadvantages concerning learning, experience, lead time developing, lack of codification, etc. (for short knowledge) as well as unfavourable conditions related to the need of new manufacturing complementarities, patents and licenses, agency and organisational issues, market access, etc.(for short capabilities).[9] The leader, by carefully choosing the specific charcateristic of the good, exploits these assymetries in knowledge and capababilities.[10]

---

[8] This feature characterises a second wave of quality-ladders models that solve problems of scale effects in the steady state growth (Segerstrom, 1998; Young, 1998), a property strongly contradicting empirical evidence found by Jones (1995): while resources allocated to R&D increase exponentially in the long-run data, productivity growth remains almost constant. For a survey on the evolution of this type of schumpeterian models see Dinopoulos and Sener (2007).

[9] For instance, Intel Inside has recently incorporated the hafnium, a new material allowing to concentrate more transistors into their microchips (45 nm processors) . This requires investments in manufacturing adaptations that give the upper-hand of Intel over its rivals.

[10] Simulating a model of management search, Rivking (2001) shows that complexity can account for the difference between replication and imitation. At certain level of complexity, neither low nor high, the incumbent is able to *replicate* a succesfull strategy within the boundaries of the firm with much less difficulties than its competitors can *imitate* it.

Regulation is usually modeled as a fixed entry cost without other consequence than the misallocation of ressources. Here, product market regulation increases the cost of technological bias. This cost of course negatively influences the leader firm value at the entry. However, it has consequences on the properties of the new good and as such, it indirectly acts as a knowledge codification device. Not only antidumping measures might do this job, but also other regulatory provision that might look like product market barriers (certifications, licences, product limitations, quality controls and the like).

The Stackelberg building block closely follows Barro and Sala-i-Martin (2004). Outsiders can be driven away from R&D races if the leader makes a commitment of high R&D investment. The credibility of this commitment relies on the (acquired) leader's technological advantages, constrained *infine* by regulation. Thus, the model yields a threshold that defines who innovates. If the leader firm is not credible, the Arrow replacement effect holds in the usual way: outsiders have more R&D incentives than incumbents, because the latter must replace themselves. As a consequence, potential entrants carry out all R&D effort and an steady state equilibrium with continuous *Schumpeterian replacement* (SR) takes place. In such equilibrium, the technological bias helps the incumbent to delay its ending date. On the contrary, if the leader firm can make a credible commitment, it will do all R&D and will remain in the market indefinitely in the context of a *permanent monopolist* (PM) equilibrium.

Each equilibrium accounts for a different effect of regulation. In the SR equilibrium, regulation increases the share of labour allocated to R&D because it limits entry deterrence. Its effect, however, depends positively on the size of the innovative steps as it represents a monopolistic premium modulating R&D incentives. On the contrary, in the PM equilibrium if regulation increases it reduces R&D intensity. The reason is that, within this equilibrium regulation consumes more labour for defensive purposes without creating enough incentives for outsiders' R&D investment.

2.2 Consumption and production

2.2.1 Consumption: instantaneous decisions

Per capita utility at each time t is given by the CES formulation:

$$u(t) = \left[\int_0^1 z(t, \omega)^{\frac{\sigma-1}{\sigma}} \, d\omega \right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

$z(t,\omega) \equiv \sum_j \gamma^j d(j,t,\omega)$ is the sub-utility function associated to each industry ω. The demand for the good of quality j at time t in industry ω is denoted by $d(j,t,\omega)$. The term γ^j captures the quality level j of a given good, where $\gamma > 1$ is a parameter representing the size of quality upgrade. Thus, within a given industry consumers preferences are ordered by the quality of the available varieties. To avoid confusions in notation, all round brackets, $()$, are reserved to the arguments of the functions of the model.

At any time, households allocate their consumption expenditure $E(t)$ seeking to maximise $u(t)$. This static problem can be separated in two components: a within-industry consumption decision and a between-industry one. Giving the utility function $z(t,\omega)$ for the quality varieties in each industry ω, all intra-industry expenditure will focus on the good j^* having the lowest quality-adjusted price: $j^* = \underset{(j)}{\arg\min} \left\{ \frac{p(\gamma^j,t,\omega)}{\gamma^j} \right\}$.

The between-industry problem concerns the allocation of total expenditure $E(t)$ among all $\omega \in [0,1]$. This consists of applying the optimal intra-industry demand $z^*(t,\omega) = \gamma^* d(j^*,t,\omega)$ to (1) and maximising $u(t)$ subject to $\int\limits_0^1 p(j^*,t,\omega)\, d(j^*,t,\omega)\, d\omega = E(t)$, which leads to the well-known CES demands:

$$d(j^*,t,\omega) = \frac{\delta(j^*,t,\omega)}{p(j^*,t,\omega)^{\sigma} \int\limits_0^1 \frac{\delta(j^*,t,\omega')}{p(j^*,t,\omega')^{1-\sigma}} d\omega'} E(t) \tag{2}$$

Where $\delta(j^*,t,\omega) \equiv \gamma^{j^*[\sigma-1]}$ is a quality level index.

2.2.2 Consumption: intertemporal decisions

Households are identical dynastic families whose number of members grows at the exogenous rate $n > 0$. Each member of a household supplies inelastically one unit of labour. Without loss of generality, initial population is set to 1, so that the population at time t is $L(t) = e^{nt}$. Using a subjective discount rate $\rho > n$, each dynastic family maximises its intertemporal utility

$$\begin{aligned} U &= \int\limits_0^{\infty} e^{-[\rho-n]t} \log u(t)\, dt \qquad (3) \\ \text{subject to } \dot{a}(t) &= w(t) + r(t)\, a(t) - E(t) - na(t) \end{aligned}$$

Where the intertemporal budget constraint links stock market gains, revenue and expenditure. $a(t)$ is the endowment of per capita assets. Its variation $\dot{a}(t)$ is decomposed into current wage income of the representative household member $w(t)$ plus stock market gains $r(t)\,a(t)$ minus expenditure $E(t)$. Between t and dt, the growth of per capita assets needs to be adjusted by population growth n. Observe that $u(t) = \frac{E(t)}{P}$, where $P = \left[\int_0^1 \left[\frac{p(j^*,t,\omega')}{\gamma^{j^*}}\right]^{1-\sigma} d\omega'\right]^{\frac{1}{1-\sigma}}$ is the utility-based price index. Since P is taking as given, the problem is equivalent to maximise $U = \int_0^\infty e^{-(\rho-n)t} \log E(t)\,dt$ subject to the intertemporal budget constraint. Solving this program leads to the well-known intertemporal optimal rule:

$$\frac{\dot{E}(t)}{E(t)} = r(t) - \rho \tag{4}$$

2.2.3 Producers and price setting

Labour is the only factor in production and is used in a technology with constant returns to scale. Each firm producing the variety ω sells its output to all members of the representative household. Thus, the firm produces a quantity of $d(j^*,t,\omega)\,L(t)$, sells at price $p(j^*,t,\omega)$ and incurs a production cost $w(t)\,d(j^*,t,\omega)\,L(t)$. After wage normalisation, $w(t) = 1$, the profit of each producer is given by:

$$\pi(j^*,t,\omega) = [p(j^*,t,\omega) - 1]\,d(j^*,t,\omega)\,L(t) \tag{5}$$

Standard monopolist profit maximisation would lead to a markup over marginal costs: $p(j^*,t,\omega) = \frac{\sigma}{\sigma-1}$. However, the monopolist is also in competition with firms offering lower quality goods. Bertrand competition yields to a limit pricing behaviour. Consider, namely, a firm laying one step behind the leader in the quality-ladder and whose best quality-adjusted price is $\frac{p(j^*-1,\omega,t)}{\gamma^{j^*-1}} = \frac{1}{\gamma^{j^*-1}}$ (i.e. its price equals its marginal cost). The leader firm will then charge $p(j^*,\omega,t) = \gamma$ and get all demands.[11]

The application of this intra-industry price setting will depend on the size of innovation γ and the monopolist power $\frac{\sigma}{\sigma-1}$. If $\frac{\sigma}{\sigma-1} > \gamma$ firms will charge $p(j^*,\omega,t) = \gamma$. On the contrary, if $\frac{\sigma}{\sigma-1} \leq \gamma$ the leader is unconstrained to charge its optimal monopolistic price rule $p(j^*,t,\omega) = \frac{\sigma}{\sigma-1}$. This introduces the following assumptions:

Assumption 1 Price setting is constrained by potential entry $\left(\frac{\sigma}{\sigma-1} > \gamma\right)$, so that $p(j^*,\omega,t) = p = \gamma$.

---

[11] A tie-break rule assumption, stating that a consumer facing similar quality-adjusted prices prefers the good with the highest quality, allows to avoid the use of a quality-adjusted price infinitesimally lower.

Assumption 2 Knowledge spillovers are such that any time an innovative firm succeeds, the previous version of the good is available for the rest of firms.

The model works with further quality upgrades of the same good. In this sense, it is more plausible to suppose, as in Assumption 1, that the size of each upgrade is not big enough to induce the innovator to adopt the same price behaviour than a monopolist having no outside competition. Assumption 2 implies that there always be a firm one step down so that the only possible price setting is this bounded limit price.[12]

Putting demands (2) into leader profits (5) and using the fact that p neither depends on j^* nor on ω yields:

$$\pi\left(j^*,\omega,t\right)=\frac{[p-1]}{p}\frac{\delta\left(j^*,\omega,t\right)}{Q\left(t\right)}E\left(t\right)L\left(t\right) \tag{6}$$

Where $Q\left(t\right)\equiv\int_0^1\delta\left(j^*,\omega,t\right)d\omega=\int_0^1\gamma^{j^*[\sigma-1]}d\omega$ is the average quality index. Thus, the monopolistic competition framework implies that firms compete in quality with the whole economy.

2.3 R&D technologies and quality improvements

At each state-of-the-art quality level j, the successful innovator of the current R&D race improves quality to the level $j+1$ and climbs the quality-ladder one step up.[13] The above-exposed price setting implies that the successful innovator becomes the sole producer in the industry. Thus, each incumbent is also the monopolist and the leader of the industry. Differently from the standard setup, in this model the incumbent does not wait until the next innovator "steals" its rents, but seeks to deter its potential rivals and to remain in the market. This section is devoted to set the underlying R&D framework allowing for these mechanisms. Before starting a subscript simplification can be made.

Subscript simplification Observe that: (i) there is only one firm producing a positive quantity in an industry; (ii) the only difference among industries concerning state variables is the current state-of-the-art quality level j; and (iii) all *endogenous* variables depend on t (except prices). Based on (i) and (ii), j_ω will now summarise the couple (j^*,ω) , which indicates the

---

[12] Further consequences of this assumption are discussed in section 2.4.1.

[13] Within a symmetric equilibrium, it is usually supposed that, at $t=0$, the state-of-the-art quality in each industry is $j=0$ and that some producer has the knowledge to fabricate a good of quality $j=0$. Firms then engage in R&D races to discover a new version of the good.

current state-of-the-art good produced by the leader of industry ω. Thanks to (iii) the time index can be dropped, keeping in mind the time dependency of the model.

2.3.1 Quality dimensions

The quality provided by a firm producing in industry ω is given by the quality vector $\overrightarrow{q}\left(j_{\omega}\right)=\left\{q_1\left(j_{\omega}\right),q_2\left(j_{\omega}\right)...,q_m\left(j_{\omega}\right)\right\}$. These m dimensions concern not only the fabricated good but also the whole business process involved in the provision of the good to the customer and related services (i.e. the integrated supply chain). The magnitude (level) of quality is summarised by the euclidean norm of the vector $\|\overrightarrow{q}\left(j_{\omega}\right)\|=\sqrt{\sum\limits_{k=1}^{m}q_k^2\left(j_{\omega}\right)}$ and the quality mix by its direction (the angle of the vector), which reflect the composition of the offered good. In line with the intra-industry sub-utility function, different mix concerning the same industry and quality level are also perfect substitutable versions of the same product. In each industry, two different quality mix provide the same utility if their magnitude is equal. Direction only matters in the research sector.

The quality state j_{ω} is the outcome of step-by-step innovations. The magnitude of the quality vector is upgraded at each step by a factor of γ, the size of innovations. The quality provided by the state-of-the-art j_{ω} is thus defined as $\|\overrightarrow{q}\left(j_{\omega}\right)\|=\gamma^{j_{\omega}}$.

2.3.2 R&D technologies

The definition of R&D technologies is based on two assumptions:

Assumption 3. While outsiders competing in a R&D race take the current quality mix as given, the current successful innovator can change it.

Assumption 4. Outsiders take a time to acquire the knowledge and capabilities to introduce a new dimension of quality into the new state-of-the-art product.

Assumption 3 reflects the innovator's advantages arising from its private knowledge about the new product. Once the new discovery come off, the new blueprint is certainly known by the innovator. The leader firm now has the choice about what visible properties its product and related services will have in the market. Assumption 4, implies that outsiders need to develop additional knowledge and capabilities to be able to replicate and improve the current state-of-art knowledge.[14]

---

[14] In a basic quality-ladders framework, outsiders *"via inspection of goods on the market, learn enough about the*

Outsiders' R&D technology Outsiders carry out R&D activities by using labour as input. R&D is governed by a Poisson stochastic process: ℓ_i units of labour allocated to research during an interval of time dt imply a probability of success $\Lambda_0\left(j_\omega+1\right)\ell_i dt$ of a new upgrade. The R&D productivity is the augmenting factor of the probability of innovative success implied by one unit of labour in the R&D process. For the outsider, the R&D productivity is defined as

$$\Lambda_0\left(j_\omega+1\right) \equiv \frac{h\cos^{\xi}\theta_{j_\omega}}{\delta\left(j_\omega+1\right)}$$

Following Li (2003), this R&D productivity is a function of the upgrade endeavoured $\left(j_\omega+1\right)$. The presence of the quality index $\delta\left(j_\omega+1\right)=\gamma^{[j_\omega+1][\sigma-1]}$ represents the idea that, as the level of quality increases, the next improvement becomes harder and R&D more costly. h is an exogenous technological parameter of R&D efficiency.

The incidence of the quality mix on R&D is captured by the normalised scalar product between the current and the previous quality vector (i.e. between $\overrightarrow{q}\left(j_\omega\right)$ and $\overrightarrow{q}\left(j_\omega-1\right)$), which is completely defined by the angle θ_{j_ω} between both vectors. That is to say:

$$\frac{\overrightarrow{q}\left(j_\omega\right)\times\overrightarrow{q}\left(j_\omega-1\right)}{\left\|\overrightarrow{q}\left(j_\omega\right)\right\|\left\|\overrightarrow{q}\left(j_\omega-1\right)\right\|}=\cos\theta_{j_\omega}$$

Recall that the $\cos\left(\cdot\right)$ function is symmetric and monotonically decreases from 1 to 0 along with $\left|\theta_{j_\omega}\right| \in [0;\Pi/2[$ (in Π radians). Hence, a change in the quality mix at quality state j_ω (i.e. θ_{j_ω}) increases the R&D difficulty faced by outsiders by a factor $\cos^{\xi}\theta_{j_\omega}$, where $\xi>0$ captures the impact of the thecnological bias. The instantaneous probability of innovation I_i implied by the R&D effort of outsider i is then:

$$I_i=\ell_i\frac{h\cos^{\xi}\theta_{j_\omega}}{\delta\left(j_\omega+1\right)} \tag{7}$$

The advantage of using a vectorial representation of quality is that, between two wave of innovations, quality dimensions need not be specified. Between the previous and the current version of the product, represented by two vectors of $\mathbb{R}^n$, all the information needed is the angle between them. The effect of technological bias collapses to the scalar product among both vectors.

---

state of knowledge to mount their own research efforts, even if the patent laws (or the lack of complete knowledge about best production methods) prevent them from manufacturing the current generation products" (Grossman and Helpman, 1991 p. 47). The "lack of complete knowledge" can be related to the way in which a new mix of quality must be incorporated into the new good, as well as the need of solutions to overcome the barrier constructed by the incumbent.

Leader's R&D technology The leader firm does not face the difficulty coming from bias. It has discovered the current state-of-the-art product and it is the sole producer that knows how to incorporate the new dimension in the manufacturing of the good. Hence, the leader's R&D productivity is:

$$\Lambda_L\left(j_\omega+1\right)=\frac{h}{\delta\left(j_\omega+1\right)}$$

2.3.3 The path of innovation and regulation

As a way to protect their position, the innovator can add a new quality dimension to the current mix in order to introduce a bias in the path of innovation. The model assumes that the discovery enables the innovator to incorporate some new component or process that exploit its asymmetries in knowledge and capabilities. This new dimension can include, for instance, new services, bundling, specific intermediate inputs, manufacturing installations, property rights, market access, vertical integrations, etc. introduced with the aim to take advantage from their complementary assets, know-how and technology. It can also be the "re-discovery" of a traditional dimension that have been dropped in the previous version of the good and for which the way to be included in the new version is by no means widely feasible because of compatibility issues or/and licensing contracting.[15]

Figure 1 illustrates the path of innovation. Let us start from the quality level j in a given industry. At this stage thee good is totally based on dimension q_1 (implying a horizontal vector). Once the next innovative firm has succeeded in upgrading the quality level to $j+1$, it introduces a bias by including dimension q_2. The firm then produces the new version of the product with a quality vector having a direction θ_{j+1} far away from the previous one. By doing so, it increases the difficulty of the next R&D race (the one leading to the $j+2$ level) by a factor of $\cos^{\xi}\theta_{j+1}$. Then, the next innovation occurs and improves the quality level to $j+2$ and do the same. Since at each discovery new dimensions are available, this process may last indefinitely. The figure suggests a case for "re-discovery" of quality dimensions. The new mix at stage $j+2$ lies completely on the plan q_2 and q_3. Dimension q_1 has been dropped ($q_1\left(j+2\right)=0$). If some compatibility concern arises after one step, the next incumbent (the winner of the $j+3th$ contest) can use again the quality dimension q_1 as a source of bias.

---

[15] Think for instance in Dolby audio technology compatible with i-Pods or, even, in the offer of organic ice creams in fast-foods. On licencing-out market imperfections see Guellec and Zuñiga's (2009) survey analysis.

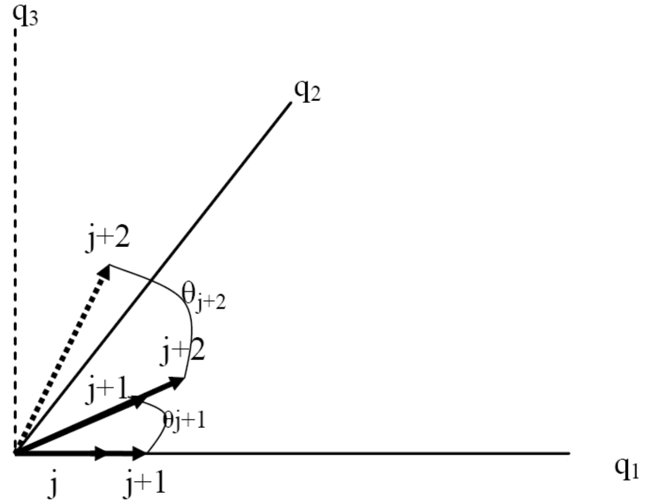

Figure 1. Innovation Path

Any leader that changes the mix incurs a variable cost (in units of labour) of adapting the new version. This cost is defined through the following functional form :

$$c\left(\theta_{j_\omega}, \psi\right) \equiv \frac{f}{\cos^{\psi} \theta_{j_\omega} \Lambda_L\left(j_\omega\right)} \tag{8}$$

where $\psi > \xi$ summarises the extent to which product market regulation limits the new version of the product. Regulation implies a cost of technological bias that increases with the change of the direction of the quality vector. Thus, in this illustration regulatory provisions are modeled as limiting complexity in the manufactured version of the improved product. The assumption $\psi > \xi$ means that regulation is supposed to be effective in limiting the new incumbent.

The cost of introducing a technological bias in the new product diminishes with the R&D productivity involved in its discovery. This captured by the term $\Lambda_L\left(j_\omega\right):$ the R&D productivity of the leader firm in the former R&D race j_ω (the one that it has won). The presence of $\Lambda_L\left(j_\omega\right)$ also implies that higher quality goods are more difficult "to bias" since R&D productivity decreases with the quality level of the industry. This rather realistic assumption helps to simplify the dynamics of θ_{j_ω}. Finally, a cost parameter f is included to take into account the measure of units of labour required to activities relating to defensive strategies.

2.4 Strategic behaviour

2.4.1 Stochastic jumps and timing

If researchers of an outsider firm i succeed, the firm get a value denoted by $v_L(j_\omega+1)$. Free entry in the research sector implies that firms enter up to the point where the expected value of innovation, $v_L(j_\omega+1)\Lambda_o(j_\omega+1)\ell_{io}dt$, equates the R&D effort ℓ_{io} invested during the infinitesimal interval of time dt. That is to say :

$$v_L(j_\omega+1)=\frac{1}{\Lambda_o(j_\omega+1)} \tag{9}$$

Given the CRS in R&D technology, the R&D effort of the outsider for a given value of a successful innovation $v_L(j_\omega+1)$ is then:

$$\ell_{io}=\begin{cases} 0 \quad if \;\; v_L(j_\omega+1)<\frac{1}{\Lambda_o(j_\omega+1)} \\ \infty \quad if \;\; v_L(j_\omega+1)>\frac{1}{\Lambda_o(j_\omega+1)} \\ \ell_{io}\in\mathbb{R}^+ \quad if \;\; v_L(j_\omega+1)=\frac{1}{\Lambda_o(j_\omega+1)} \end{cases} \tag{10}$$

Let $\ell_0=\sum_i \ell_{i0}$ be the total amount of R&D carried out by outsiders. The Bellman equation of a (potential) innovative leader can be written as

$$\begin{aligned} rv_L(j_\omega) &= \pi_L-\ell_L+\ell_L\Lambda_L(j_\omega+1)\left[v_L(j_\omega+1)-v_L(j_\omega)\right] \\ &\quad -\ell_o\Lambda_o(j_\omega+1)v_L(j_\omega)-c(\theta_{j_\omega},\psi) \end{aligned} \tag{11}$$

If the leader invests ℓ_L in R&D, with instantaneous probability $\ell_L\Lambda_L(j_\omega+1)$ its optimal value $v_L(j_\omega)$ can jump to $v_L(j_\omega+1)$ thanks to the new discovery. With instantaneous probability $\ell_o\Lambda_o(j_\omega+1)$ the leader may be replaced by a successful outsider. In the meantime, the leader firm enjoys its monopolist profits π_L and pays ℓ_L unit of labour for new discoveries as well as $c(\theta_{j_\omega},\psi)$ units of labour for defensive strategies.[16]

Assumption 2 implies that the maximum gap attained is one step. Therefore, an asymmetry in price setting incitations will not arise here. Even if the leader innovates it will not get enough technological distance to practice a monopolistic price that would give him more incentives to innovate compared to an outsider that must charge a Bertrand price when innovations are non-

---

[16] Equation (11) implicitly says that the current value of a follower is zero. This is the result of Bertrand competition, the free entry condition with CRS and zero R&D *sunk* cost to be payed before playing.

radical (see Denicolò, 2001). This assumption allows to focus, by construction, on incitations stemming from R&D advantages.

Built on this setting, the timing of the model is as follows:

1. Nature : At the very beginning of the technological state j_ω, the nature provides the leader (the current successful innovator), symmetric R&D technologies and the parameters of the model, namely the level of regulation. Free entry in the research sector applies.

2. Entry into the product market : the leader chooses the level of bias θ_{j_ω} in order to maximise its value. It takes the parameters of the model as given, namely the level of product market regulation. Production starts.

3. R&D race :

   (a) The leader decides its optimal level of R&D effort ℓ_L taking θ_{j_ω} as fixed and knowing outsiders reaction (10)

   (b) Having observed the leader's commitment ℓ_L, outsiders set their optimal R&D effort ℓ_o

Once investments are engaged, they remain fixed during the contest. Namely, the leader cannot change its choice of θ_{j_ω}. The flow cost $c\left(\theta_{j_\omega}, \psi\right)$ can then be seen as the amortised defensive investment per-time interval *dt*. Stage 3 is the core of the Stackelberg game based on Barro and Sala-i-Martin (2004) model. A key difference is that the relative cost advantages are endogenous thanks to stage 2.

2.4.2 The Stackelberg game

The following proposition establishes the conditions under which outsiders are deterred. The presentation focuses on the case where $\theta_{j_\omega} = \theta$ is constant. In section 2.3.3, this will prove to be true for a constant outsider menace, which is the standard steady state condition of this kind of model.

Proposition 1 *For a constant value of $\theta_{j_\omega} = \theta$, a sufficient condition to ensure a non profitable R&D effort for outsiders is*

$$\cos^{\xi}\theta \leq \left[1 - \gamma^{-[\sigma-1]}\right] \tag{12}$$

Under this condition, the leader's R&D effort can be positive and irrespective of outsider actions. In this equilibrium the leader value and the interest rate verify, respectively

$$v_L\left(j_\omega\right) = \frac{\pi_L - c\left(\theta, \psi\right)}{r} \tag{13}$$

$$r = \frac{p-1}{p} \frac{E\ L\left[1 - \gamma^{-[\sigma-1]}\right] h}{Q} \tag{14}$$

Proof. See Appendix A.1.1.■

The inequality stated in (12) will be referred to as the credibility condition. Intuitively, it defines a threshold for the R&D productivity advantage of the leader$\left(\frac{\Lambda_L(j_\omega+1)}{\Lambda_o(j_\omega+1)} = \frac{1}{\cos^\xi \theta}\right)$, which is increasing in θ (i.e. decreasing in $\cos^\xi \theta$). This threshold determines whether the R&D investment is profitable for the leader firm (i.e. whether it is credible). If this is the case, constant returns of R&D investment imply that the leader can potentially perform enough R&D effort to put outsiders out of competition. Thus, when the bias is strong enough, the leader does carries out research effort and the outcome is that the value of the next quality improvement is lower than the R&D cost incurred by outsiders $v_L\left(j_\omega + 1\right) < \frac{1}{\Lambda_o(j_\omega+1)}$ (see the proof of Proposition 1 for details). As a consequence, outsiders react by setting zero R&D effort, meaning no replacement menace: $I_o = \sum_i I_{io} = 0$. In this case the leader value is given by (13). In contrast, if the credibility condition does not hold, the leader will be replaced and all R&D will be done by outsiders. Its value in such a situation is that implied by (11) for $\ell_L = 0$. The *ex ante* value of the incumbent can be summed up as:

$$v_L\left(j_\omega\right) = \begin{cases} \frac{\pi_L - c(\theta,\psi)}{r + \ell_o \Lambda_o(j_\omega+1)} & if\ \ \cos^\xi \theta > \left[1 - \gamma^{-[\sigma-1]}\right] \qquad (a) \\ \frac{\pi_L - c(\theta,\psi)}{r} & if \cos^\xi \theta \leq \left[1 - \gamma^{-[\sigma-1]}\right] \qquad (b) \end{cases} \tag{15}$$

2.4.3 The choice of the bias

At the moment in which the leader enters into the product market (i.e. when it introduces the new good), outsiders can potentially carry out research efforts and the free entry condition in the research sector holds. Thus, the rationale of the decision of bias starts by considering that, at this stage, no technological advantage has been acquired. The leader firm is not credible for the moment and its value is given by (15,a). Potentially, a new successful innovator can replace it. But the leader can make this task harder. A higher R&D difficulty means a lower probability of replacement and then a higher expected value. This decision of bias implies a cost of $c\left(\theta_{j_\omega},\psi\right)$ units of labour which is increasing in ψ, the regulation parameter. The leader firm will choose a value of θ_{j_ω} that maximises its value.

Define $I_{oL}\equiv\ell_o\Lambda_L\left(j_\omega+1\right)$ as the *potential menace of outsiders*, that is the probability of outsiders' innovative success in the absence of any bias (i.e. when $\theta_{j_\omega}=0$). The Bellman equation of the leader before its credibility has been acquired can be then written as:

$$rv_L\left(j_\omega\right)=\pi_L-I_{oL}\cos^{\xi}\theta_{j_\omega}v_L\left(j_\omega\right)-c\left(\theta_{j_\omega},\psi\right) \tag{16}$$

Proposition 2 *When free entry in the research sector holds, there exists an optimal choice of bias if its impact* (ξ) *is high enough. Its value is constant for a constant potential outsider menace* (I_{oL}) *and is given by*

$$\cos\theta=\left[\frac{\psi f}{\xi I_{oL}}\right]^{\frac{1}{\psi}} \tag{17}$$

Proof. See Appendix A.1.2.■

As expected $\cos\theta$ decreases with I_{oL}. A higher potential menace of replacement implies a more aggressive defensive strategy. Moreover, for a given value of I_{oL} regulation reduces the bias.[17] Recalling that outsiders' (*de facto*) probability of R&D success is $I_o=I_{oL}\cos^{\xi}\theta$, one easily verifies:

$$I_o=I_{oL}^{\frac{\psi-\xi}{\psi}}\left[\frac{\psi f}{\xi}\right]^{\frac{\xi}{\psi}} \tag{18}$$

This hazard rate converges toward its potential $I_o\rightarrow I_{oL}$ when $\psi\rightarrow\infty$. Hence, a high level of regulation may (asymptotically) eliminate the bias ($\cos\theta\rightarrow1$).

In particular, ψ can determine whether the credibility condition holds. For a low enough level of regulation, the bias delivers credibility. In that case the economy jumps to a permanent monopolist framework with an innovative leader whose value is that of equation (15,b). The choice of θ in this limit case is established by Proposition 3.

---

[17] Taking I_{oL} as given, $\frac{\partial\cos\theta}{\partial\psi}=\cos\theta\left[\frac{1-\log\left[\cos^{\psi}\theta\right]}{\psi^2}\right]>0$ since $\log\left[\cos^{\psi}\theta\right]<0$.

Proposition 3 *When the leader credibility is ensured, the optimal value of bias is*

$$\cos^{\xi}\theta = \left[1 - \gamma^{-[\sigma-1]}\right] \tag{19}$$

Proof. It follows immediately from (15,b).■

Here the incumbent enjoys permanent profits as an innovative monopolist. Once this dominant position has been achieved, higher level of bias will only increase costs without additional value. Therefore, the leader does not need further R&D advantages beyond the credibility point.

Thus, two type of equilibriums can arise. In the first case, outsiders do all R&D and the leader delays its replacement in a *Schumpeterian replacement equilibrium* (SR). In the second situation, the leader may become the sole innovator enjoying permanent profits in a *Permanent monopolistic equilibrium* (PM). To identify the underlying conditions of each type of equilibrium, the schedule of decisions studied so far needs to be completed with the macro steady-state analysis. This is what the next section does.

2.5 Global accounting and steady state

Given the semi-endogenous nature of the innovation rate, the anlysis here consists in identifying the *potential menace of ousiders* that underlies the *de facto* innovation rate at equilibirum. Since this menace trigger the defensive reaction of the leader, whe then analyse how regulation affects the choice of the leader at equilibirum and, thereby, the steady-state equilibrium itself.

2.5.1 The Schumpeterian replacement equilibrium

The macro equilibrium for a continuum Schumpeterian replacement is given by the fulfillment of the labour market clearing and the free entry condition in the research sector. Labour market clearing under full employment needs the addition of labour used in research $L_r = \int_0^1 \ell_o\left(j_\omega + 1\right) d\omega$, manufacturing $L_y = \int_0^1 L\ d\left(j_\omega\right) d\omega$ and defensive activities related to technological bias $L_f = \int_0^1 c\left(\theta,\psi\right)\ d\omega$. The focus here is the symmetric steady state equilibrium in which expenditure E and outsiders innovation rate I_0 are constant. The latter implies that I_{0L} is also constant and so $\cos\theta$. Using the definition of the average quality index Q introduced in equation (6) and the quality index of each industry $\delta\left(j_\omega + 1\right) = \gamma^{[j_\omega+1][\sigma-1]}$, the demand for labour in research activities is given by:

$$L_r = \frac{I_o \gamma^{\sigma-1}}{h \cos^{\xi} \theta} Q \tag{20}$$

After including demand equation (2), labour required for manufacturing is:

$$L_y = L \frac{E}{p}$$

To obtain the labour demand for defensive activities, the definition of $c\left(\theta,\psi\right)$ in (8) and the average quality index are used to obtain [18]:

$$L_f = \frac{f}{h \cos^{\psi} \theta} Q$$

The full employment condition requires that $L = L_y + L_r + L_f$, which is equivalent to:

$$1 = \frac{E}{p} + \frac{I_o \gamma^{\sigma-1}}{h \cos^{\xi} \theta} \frac{Q}{L} + \frac{f}{h \cos^{\psi} \theta} \frac{Q}{L} \tag{21}$$

To include the free entry, the firm value of the replacement case (15,a) is substituted on the RHS of (9) and the outsiders' R&D productivity for constant values of I_{oL} and $\cos\theta$ on the LHS. In addition, equation (4) must be verified at $\frac{\dot{E}}{E} = 0$, so that $r = \rho$.

$$E = \frac{Q}{L} \frac{p}{p-1} \left[\frac{\rho + I_0}{h \cos^{\xi} \theta} + \frac{f}{h \cos^{\psi} \theta} \right] \tag{22}$$

Clearly, in a steady-state equilibrium in which I_{oL} and E are constant, $x \equiv \frac{Q}{L}$ must also be constant. Hence, population and average quality must grow at the same rate:

$$\frac{\dot{Q}}{Q} = \frac{\dot{L}}{L} = n \tag{23}$$

Therefore, the model builds on the same tractable properties of a standard semi-endogenous growth model without scale effects.[19] The rate of growth of Q is obtained in the usual way. Using the law of large numbers, the variation of average quality is computed by adding the expected technological jump of each industry: $\dot{Q} = \int_0^1 I_o \left[\delta\left(j_\omega + 1\right) - \delta\left(j_\omega\right)\right] d\omega$. After using the definition of Q, this expression reduces to:

---

[18] Because industries are symmetric in probabilities, $\cos^{\psi}\theta$ (which depends on I_{0L}) can be considered as a constant inside integrals.

[19] After putting demands (2) into the instantaneous utility (1), taking logs and differencing, the growth of the average quality implies the standard steady-state utility growth $\frac{\dot{u}(t)}{u(t)} = \frac{n}{\sigma-1}$.

$$\frac{\overset{\bullet}{Q}}{Q} = I_o \left[\gamma^{\sigma-1} - 1\right]$$

In steady state, condition (23) must hold. Thus, the innovation rate is:

$$I_o = \frac{n}{\left[\gamma^{\sigma-1} - 1\right]} \tag{24}$$

Using this result and equation (18), the consequent *steady-state potential menace of outsiders* is:

$$I_{oL} = \left[\frac{n}{\left[\gamma^{\sigma-1} - 1\right]\left[\frac{\psi f}{\xi}\right]^{\frac{\xi}{\psi}}}\right]^{\frac{\psi}{\psi-\xi}} \tag{25}$$

The technological bias in steady-state in the SR equilibrium is obtained by putting (25) into (17), which leads to:

$$\cos^{\xi}\theta = \left[\frac{\left[\gamma^{\sigma-1} - 1\right]\psi f}{\xi n}\right]^{\frac{\xi}{\psi-\xi}} \tag{26}$$

The steady-state level of bias keeps the property of the partial equilibrium decision: when $\psi \rightarrow \infty$ the bias vanishes ($\cos^{\xi}\theta \rightarrow 1$). By constraining the possibilities of bias, regulation ψ is at the core of the jump from continuous firm renewal (the SR equilibrium) to a permanent leadership (the PM one). This result is expressed in the following proposition.

Proposition 4 *For $\psi > \xi$ there exists a unique level of regulation $\left(\overline{\psi}\right)$ defining the threshold between the Schumpeterian replacement and the permanent monopolist cases involved in the value of the leader firm (15).*

Proof. See Appendix A.1.3.■

Figure 2 illustrates the steady-state decision of bias given the value of regulation. For $\psi \in \left]1, \overline{\psi}\right[$ the bias is set following equation (19). Thereafter, the leader must take into account free entry of outsiders and decides accordingly to 26).

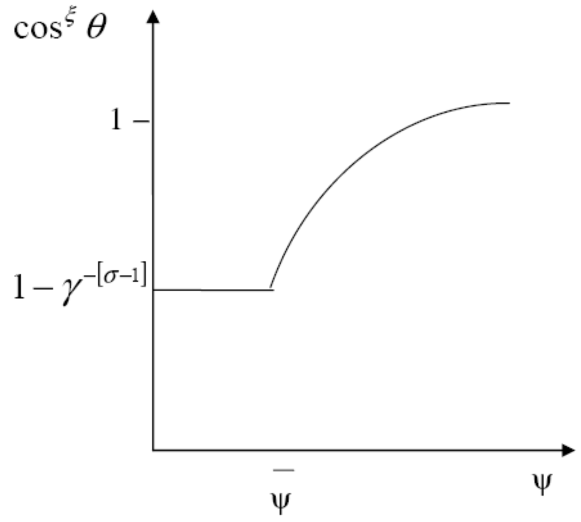

Figure 2. Leader's optimal choice of bias

The effect of regulation on R&D effort in steady-state can be analysed through the share of labour allocated to research $s_r \equiv \frac{L_r}{L}$. This share can be obtained from the system of equations (21) and (22) for two unknowns: $x \equiv \frac{Q}{L}$ and E . Solving this system for x and using L_r as expressed by (20) gives:

$$s_r = \frac{1}{\Gamma_{rep} + \frac{\xi p}{\gamma^{\sigma-1}[p-1]\psi}} \tag{27}$$

Where $\Gamma_{rep} \equiv 1 + \frac{[1-\gamma^{-[\sigma-1]}]\rho}{[p-1]n} + \frac{1}{\gamma^{\sigma-1}[p-1]}$. The following proposition can now be stated.

Proposition 5 *In the Schumpeterian equilibrium, regulation* (ψ) *increases the labour share allocated to R&D* (s_r) *and its effect is all the more important that the size of innovation* (γ) *is bigger.*

Proof. See Appendix A.1.4.■

As R&D becomes harder, at equilibrium, less firms will be willing to enter the R&D race. The aggregate labour allocated to R&D then decreases. The size of innovation increases marginal revenues as well as the cost of climbing the quality-ladder in the next R&D race. Both Schumpeterian channels combine to modulate the R&D incentives stemming from bias reductions. For $p = \gamma$, the multiplicative factor of ψ in (27) is increasing in γ: the effect of regulation is positively conditioned by the size of innovation (see the appendix for a formal proof).

2.5.2 The permanent monopolist equilibrium

In a situation with a permanent monopolist, the free entry condition in the research sector no longer holds. Instead, the steady-state equilibrium condition is given by the interest rate (14) that allows a positive and finite amount of research. In this equilibrium some minor adaptations for labour market clearing must be considered. First, the monopolist allocate labour to research without being affected by the bias. Its probability of innovative success is then $I_L = \ell_L \Lambda_L$. Second, the optimal choice of bias is now given by $\cos^{\xi}\theta = \left[1-\gamma^{-[\sigma-1]}\right]$. Full employment requires:

$$1 = \frac{E}{p} + \frac{I_L \gamma^{\sigma-1}}{h}\frac{Q}{L} + \frac{f}{h\left[1-\gamma^{-[\sigma-1]}\right]^{\frac{\psi}{\xi}}}\frac{Q}{L} \tag{28}$$

As before, if expenditure and innovation rates are constant, then $\frac{\dot{Q}}{Q} = \frac{\dot{L}}{L} = n$. Thus the steady-state rate of innovation remains the same: $I_L = \frac{n}{[\gamma^{\sigma-1}-1]}$.[20]

Putting the interest rate (14) into the optimal path of expenditure (4) implies:

$$E = \frac{\rho}{\left[1-\gamma^{-[\sigma-1]}\right]h}\frac{Q}{L}\frac{p}{p-1} \tag{29}$$

The steady-state share of labour allocated to R&D $s_{rm} = \frac{L_r}{L}$ for the permanent monopolistic case can be obtained by substituting E, as defined by (29), into labour market clearing (28) for I_L at the steady state. This yields:

$$s_{rm} = \frac{1}{\left[\Gamma_{per} + \frac{f}{n\left[1-\gamma^{-(\sigma-1)}\right]^{\frac{\psi}{\xi}-1}}\right]} \tag{30}$$

Where $\Gamma_{per} \equiv 1 + \frac{\rho}{n[p-1]}$.

Proposition 6 *In the permanent monopolist equilibrium, regulation* (ψ) *reduces the share of labour allocated to R&D* (s_{rm}).

Proof. See Appendix A.1.5.■

In this equilibrium the monopolist is the innovator. If regulation increases, but not enough to ensure a continuous monopolistic replacement, resources that potentially can by employed in

---

[20] Since E is constant, consumption growth is still given by $\frac{\dot{u}(t)}{u(t)} = \frac{n}{\sigma-1}$.

R&D must be allocated for defensive activities. The R&D effort then decreases.

3 Evidence

Accordingly to the model, the reasons to expect a positive correlation between regulation restrictions and R&D intensity is that they set the boundaries under which the innovative activity is conducted. Within a second best context, rather than limiting the scope for innovative improvements these rules may act as a market coordination device able to deliver standardisation and knowledge diffusion. This coordination may probably be a *de facto* consequence of some practices usually seen as market barriers. This section empirically analyses this possibility at the industry level.

3.1 Empirical strategy

Industry-level data has the advantage of exploiting heterogeneity in R&D effort coming from different competitive environments. It also captures phenomenons that are aggregate in nature, similar to those analysed in the model. However, as it well is the case with most micro data sets, information on potential entrants (outsiders) is not available. Therefore, it is not possible to analyse in detail the conditions under which the SR and the PM equilibrium arise. Some practical guidelines must be assumed in order to link the model with the data.

Notice that the outcome of zero R&D effort comes from the choice of CRS in R&D, the standard assumption used for tractability. In practice, monopolists are replaced, even if they remain for a long period of time. Consequently, the empirical exercise starts assuming that, in average, industries are mainly concerned with the Schumpeterian equilibrium (sections 3.3.2 and 3.3.3). Section 3.3.4 then moves one step forward in identification and study how these results change when low- and high-regulation environments are analysed separately.

High-technology industries (HT) are assumed to make bigger innovative steps than the rest of industries. They are defined as 30-33 ISIC Rev-3 industries. This includes the information and communication technologies (ICT industries) and the manufacturing of medical precision and optical instruments. The robustness check section (3.3.2) tests an alternative definition including industries 29 (machinery and equipment) and 34 (motor vehicles), usually seen as using intensely ICT technologies. It is expected that the kind of innovation of HT industries allows for relatively high monopolistic incentives. If this is true and if in average industries are in a Schumpeterian equilibrium, the R&D incentives induced by regulation should be higher in

HT.

Let y_{it} be the measure of aggregate R&D effort (labour share in the model) of industry i at time t. Denoting r_{it} the regulation proxy and HT the dummy variable identifying HT industries, the following equation is estimated:

$$y_{it} = \alpha_1 \; r_{it} + \alpha_2 \; r_{it} \times HT + \alpha_3 \; HT + \alpha_5 x_{it} + \epsilon_{it} \tag{31}$$

where $\epsilon_{it} = \eta_i + \mu_{it}$, x_{it} is a vector of controls (see section 3.2.2) and all continuous variables are in natural logs. Under this specification, the marginal effect of regulation can be computed as

$$\frac{\partial E\left[y_{it}|HT\right]}{\partial R_{it}} = \alpha_1 \; + \alpha_2 \; HT$$

If $HT = 0$ then the marginal effect is α_1 and reflects the effect of regulation on non-HT industries. When $HT = 1$ the marginal effect is $\alpha_1 \; + \alpha_2$. This means that α_1 is also the effect of regulation which is common to HT and non-HT industries. Hence, α_2 is the effect of regulation on R&D intensity in HT industries *relative* to non-HT ones.

The Schumpeterian equilibrium predicts a positive effect of regulation on R&D intensity that increases with the size of innovation. Using the full sample, a positive and significant estimate $\widehat{\alpha}_2$ is expected. In other words, if an R&D-boosting effect of regulation can be expected following the model, it is more likely to be observed in the specificity of high technology industries. In *absolute* terms, the over all effect of regulation on R&D intensity in HT industries will be given by $\widehat{\alpha}_1 \; + \widehat{\alpha}_2$. While the significance of $\widehat{\alpha}_2$ can be obtained directly from the regressions, for $\widehat{\alpha}_1 \; + \widehat{\alpha}_2$ the joint significance $\frac{\widehat{\alpha}_1+\widehat{\alpha}_2}{\sqrt{\widehat{\sigma}_{\widehat{\alpha}_1\widehat{\alpha}_1}+\widehat{\sigma}_{\widehat{\alpha}_2\widehat{\alpha}_2}+2\widehat{\sigma}_{\widehat{\alpha}_1\widehat{\alpha}_2}}}$ is required, where $\widehat{\sigma}_{ab}$ is the sample covariance between a and b.

It is probable that a fixed component in the error term is associated to each country-industry couple. The bias produced by this unobserved time-invariant heterogeneity can be eliminated by a within-group estimator, but at the cost of losing the information provided by $\widehat{\alpha}_3$. When substracting the sample mean of each variable by group, the transformation of the within-group estimator eliminate η_i, but also all time-invariant variables such as HT. However, the fixed effect will contain the dummy HT, so that the estimates of $\widehat{\alpha}_2$ and $\widehat{\alpha}_1 + \widehat{\alpha}_2$ should remain consistent. In the robustness checks, use is made of the three-steps fixed-effect decomposition proposed by Plümper and Troeger (2007) that helps to handle this type of time-invariant variable when there are reasons to suspect individual unobserved heterogeneity.

3.2 Data

3.2.1 R&D and regulation

The data set contains information for 14 manufacturing industries across 14 OECD countries for the period 1987-2003. R&D series are provided by the OECD ANBERD dataset. The sample period is mainly limited by R&D data availability. The dependant variable, R&D intensity, is measured as R&D expenditure over value added. The latter series were obtained from the 60-Industry database of the Groningen Growth and Development Centre (GGDC).[21] Appendix (A.2) gives a summary of the sample.

Indicators of regulation are computed by the OECD.[22] Their attractiveness is that they rely on administrative practices that are usually seen as market barriers. These practices are collected and coded for specific areas of regulation and give the basis to compute what the OECD calls low-level indicators. To construct aggregate indicators, a bottom-up approach is implemented using weights that seek to reflect information availability and the nested structure of the areas included in the aggregate indicator. Four global indicators of regulation are used.

- The economy-wide indicator of product market regulation (henceforth PMR): It is composed of a collection of inward- and outward-oriented indicators of market barriers reflecting state control, barriers to entrepreneurship and barriers to trade and investment a the national level. While close to regulatory practices its availability in time dimension is a drawback. It is only available for 1998 and 2003 and has been consequently distributed into the sample before and after 2000.[23]

- The Size and scope of the public enterprise sector (henceforth PMR-Public): It is an important low-level component of PMR that captures the degree of active participation of the state in product markets. One can expect that R&D activities and firm operation where the State is strongly active are more restricted.

- The indicator of network sectors (henceforth ETCR): It is an indicator of regulation in seven sectors related to energy, transport and communication (telecoms, electricity, gas,

---

[21] http://www.ggdc.net/databases/60_industry.htm

[22] www.oecd.org/eco/pmr

[23] This arbitrary distribution seeks to reflect the timing of surveys and, under a fixed-effect specification, it should have minor consequences on estimations.

post, rail, air passenger transport, and road freight). It is available in times-series at the country level and focuses on areas such as barriers to entry, public ownership, market structure and price controls. As network sectors have been one of the main target of wider deregulation policies, they help to capture the evolution of the competitive environment at the national level.

- The impact of service regulation on manufacturing (henceforth REGIMP): It captures the "knock-on" effects associated to regulation in (i) network services; (ii) retail distribution and professional business services (RBSR) and (iii) finance. Information on regulation in retail and business services deals with barriers to entry, price controls and constrains on business operations for 1998 and 2003. Regulation on the financial sector stems from De Serres et al. (2006) who provide regulatory practices on the banking system and financial instruments in the period 2002-2003. The projection of regulation of services sectors on manufacturing industries is made accordingly to input/output matrices informing about the use of these sectors as intermediates inputs. The main advantage of this indicator is that it is available in the form of time-series cross-section data.

The details of the methodology, questionary and construction of PMR can be found in Conway et al. (2005). The methodology and analysis related to REGIMP and ETCR is fully documented in Conway and Nicoletti (2006). While REGIMP and ETCR are more indirect measures of product market competition, they remain highly correlated to the PMR aggregate indicator (78% and 64%, respectively) and have the advantage of providing information in time series. For these reasons they will be emphasised in the presentation of the empirical results, specially REGIMP which presents a pseudo-panel variability compatible with that of the explained variable.

An important question is the extent to which these indicators reflect the kind of regulation described in the model. In the theoretical setting regulation is seen as a device constraining the way in which the new discovery is introduced into the market. While the OECD indicators are constructed with the aim of capturing practices supposed to curb competition, by definition, they measure barriers that limit the action of actors. In this sense, REGIMP has the advantage of capturing the restrictions induced by utility sectors (network services, retail, business services and finance) on the provision and fabrication of manufactured goods. Domestic regulation in these sectors will particularly shape entry and operation in manufacturing industries as they represent key inputs, mainly produced by natural monopolies where import penetration plays a minor rôle. For instance, some of the practices considered by the indicators of regulation in retail and professional services include limitations such as licensing permits, restrictions on entrepreneurial choices and on the type of products that can be offered (see Conway and Nicoletti, 2006 Appendix). Firms that use theses services will be probably constrained in their implementation of new business solutions. Similarly, restrictions on the furniture of communication, transports and energy will clearly delimit the way to introduce new goods on the market.[24]

3.2.2 Other explanatory variables

In order to control for alternative determinants of R&D intensity, the following variables are considered:

- R&D spillovers: as stressed by several works in endogenous growth, controlling for the innovative effort performed at the world level, helps to take into account the knowledge externalities as well as the possible strategic complementarity in R&D investments. For each country, industry and period these externalities are proxied by the R&D intensity performed by the rest of countries in the same industry. As they vary in both cross-section and time dimension, R&D spillovers are a good indicator of the evolution of the international technological context of each individual (country-industry couple).

- Proximity to the technology frontier: The technology gap of the industry vis-à-vis the world technology frontier can be an important determinant of innovation and, as such, of the innovative underlying effort. Industries competing close to the frontier may require more adaptation to technological change and so more innovative effort than laggards ones. For a given period, the proximity to the technology frontier is measured as the labour productivity of each country-industry couple relative to the highest one observed at the world level in the same industry. In order to provide a more accurately identification of the most productive industry, the transversal deflation of value-added uses PPAs at the industry level, provided by Timmer et al. (2007) for 1997.

- Capital intensity: Capital can be correlated to R&D effort by several channels. While it can render search routines more efficient it can also be a substitute in the case of industries that heavily rely on embodied technical change. On the other hand, because of

---

[24] Conway and Nicoletti (2006) report that in the late 1990 roughly 80% of the output of business services was used as intermediate in other sectors of the economy and that finance, electricity, post and telecommunication sectors accounted represented between 50%-70% of intermediate inputs in production processes.

complementarities between high-skills and capital, these indicator may indirectly correct for potential bias induced by the omission of variables related to human capital endowment Capital intensity is computed as the ratio of deflated capital stock (from OECD STAN) to hours worked (GGDC). Capital stock has been obtained from cumulative investments thanks to a perpetual-inventory rule using a 7% depreciation rate. The main drawback of these series is the lack of availability of information for some countries, which translates into a reduction of roughly half of the sample. Related results should be then analysed with caution.

- Financial deepness: It is included since innovation can be constrained not by the lack of incentives but by financial market imperfections. Financial development is proxied by the ratio of total asset investment of institutional investors over GDP available from the OECD (Institutional Investor database).

3.3 Results

3.3.1 A differentiated impact of regulation depending on the technological level

Table 1 reports the main results using the full sample. Within-group regressions are presented considering Huber-White corrected standard errors. The impact of R&D spillovers (R&D intensity of the rest of the world in the same industry) on R&D intensity is significantly positive in all specifications. Indeed, this correlation appears in most of regressions. Column [1] and [2] presents regressions using the "knock-on" effect of non-manufacturing regulation on manufacturing activities, captured by the regulation proxy REGIMP. It represents the widest source of variance as it is available in time-series cross-section data. Following REGIMP, regulation does not account for a significant effect on R&D intensity in non-HT industries . However, in line with what can be deduced from the model's prediction, one observes a positive effect of regulation which is specific to HT industries. This is true in relative and absolute terms. In relative terms this result is given by the positive and significant coefficient of the interaction between REGIMP and the dummy variable defining high-tech industries. In absolute terms, this positive correlation is shown by the marginal effect (ME) computed in the bottom part of Table 1. As explained above, this ME considers both (a) the effect of regulation that is common to HT and non-HT industries ($\widehat{\alpha}_1$ in equation 31) and (b) the effect of regulation that is specific to HT industries ($\widehat{\alpha}_2$ in equation 31). It could be argued that the data structure might imply intra-group correlation. The same regressions have been run using both Huber-White correction of standard errors and clustering at the industry level. The table reports the clustered standard errors for the marginal effect in squared brackets. One easily verifies that the significance of the ME is still preserved at conventional levels under this heteroskedasticity robustness check.

These results are confirmed by the regulation proxy ETCR (columns [3] and [4]) that measures regulatory provisions in network sectors. As suggested by (Conway and Nicoletti, 2006), this indicator mirrors the trend of regulatory reforms at the national level.[25] Interestingly, here, in the basic model of column [3], regulation presents a significantly positive correlation with R&D intensity. As before, one the interaction is included, a differentiated effect appears. Both the interaction term and the ME suggest a positive impact of regulation on HT industries. This is also robust to the clustered correction of the standard errors.

Results are slightly different for the product market regulation proxy PMR (columns [5] and [6]). PMR is an aggregate of economy-wide indicators aiming at capture market barriers. It does not vary in every period. Two points in time are available. This is probably the main reason for some changes in the estimations. Now, in the simple model (column [5]) regulation appear to be negatively associated to R&D. This is also true for the effect of regulation in non-HT technologies in column [6]. In this regression, a positive and significant interaction between regulation and HT industries shows up. Hence, PMR regressions illustrate more sharply the differentiated effect of regulation depending on the technological level. The sum of the positive R&D effect of regulation in HT industries and the negative one, common to all industries, yields a non significant overall ME.

The last two columns focus, among market barriers summarised in PMR, on the size and the scope of the public sector (PMR-Public). One should expect that a higher and active state imposes higher regulation, namely in the production of new varieties. As in the case of ETCR, the effect of regulation in the simple model is again positive and significant for PMR-Public (column [7]). The differentiated effect of regulation is also suggested here. Namely, one observes a positive correlation between regulation and R&D effort in HT industries. This time, contrary to the aggregate PMR indicator, this also true in absolute terms and robust to clustering.

Overall these results based on the full sample are in line with the main model's prediction regarding the Schumpeterian equilibrium. As regulation increases, the dissuasive effect of defensive strategies can be reduced. R&D incentives are higher, but the final impact of regulation

---

[25] Usual rankings of regulation at the national level are quite in line with the picture generated by this indicator. For instance, in average in our sample, Greece and Italy appear as the most regulated countries. UK and US on the contrary are in the opposite extreme.

is modulated by the size of innovation since it shapes monopolist incentives. This prediction implies that the positive effect of regulation should empirically be found when the size of innovation is higher. This is confirmed by the estimates of the interaction term in all regressions and by the overall marginal effect in almost all of them, namely in those using the most efficient proxies of regulation.

Table 1. Dependent Variable: R&D/VA - Within-group estimates

Basic control regressions

	REGIMP		ETCR		PMR		PMR-Public	
	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]
R&D Spillovers	0.146***	0.195***	0.134***	0.196***	0.140***	0.188***	0.142***	0.186***
	(0.046)	(0.042)	(0.045)	(0.040)	(0.046)	(0.044)	(0.051)	(0.050)
Regulation	0.001	-0.166	0.254***	0.019	-0.727***	-0.908***	0.663***	0.130
	(0.127)	(0.125)	(0.082)	(0.068)	(0.233)	(0.240)	(0.234)	(0.245)
Regulation x HT		1.739***		0.715***		0.826***		2.076***
		(0.225)		(0.088)		(0.144)		(0.461)
Constant	-2.610***	-1.789***	-3.048***	-2.768***	-2.192***	-2.050***	-3.913***	-3.797***
	(0.537)	(0.628)	(0.420)	(0.353)	(0.215)	(0.385)	(0.307)	(0.293)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Obs	2754	2754	2754	2754	2754	2754	2546	2546
Number of groups	189	189	189	189	189	189	176	176
Marginal effect		1.573***		0.734***		-0.082		2.206***
		(0.256)		(0.117)		(0.226)		(0.438)
		[0.597]		[0.300]		[0.384]		[0.769][

Notes: Hubert-White corrected standard errors in round parentheses and clustered at the industry level in squared brackets; *, **,*** denote significance at 10%, 5% and 1%, respectively

3.3.2 Robustness checks

This section analyses whether the above-presented results are due to potential bias such as the omission of time-varying controls, the definition of the HT industries or the elimination of the dummy HT in the within-group regressions.

Full set of controls Table 2 presents results using the full set of available controls. The conclusions presented in the previous analysis also hold for these regressions. The same pattern emerges: a positive effect of regulation on R&D intensity in HT industries, both in relative and absolute terms. The ME using REGIMP is even robust to clustering, despite the heavily reduced sample size. While in general the new controls present a weak correlation, they appear with the expected sign when the level of significance is attained. This is the case of the capital labour ratio and financial assets over GDP in those regression using time-varying indicators (REGIMP and ETCR). The lack of availability of capital stock heavily constrains the sample size and so the efficiency of estimations. This probably the reason why no conclusions can be drawn from the proximity to the frontier. Consistent with the previous results, the proxy of international R&D spillovers is also positively associated with R&D intensity. The increased magnitude of its coefficient and the wide compatibility of these results with those of Table 1, suggest that they help to control for the unobserved heterogeneity that varies during time.

Table 2. Dependent Variable: R&D/VA - Within-group estimates

Full control regressions

	REGIMP	ETCR	PMR	PMR-Public
R&D Spillovers	0.342***	0.364***	0.331***	0.318***
	(0.069)	(0.066)	(0.070)	(0.071)
Regulation	-0.300	-0.384***	-0.262	0.371
	(0.221)	(0.105)	(0.332)	(0.321)
Regulation x HT	1.558***	0.817***	0.641***	0.818*
	(0.288)	(0.123)	(0.188)	(0.418)
Proximity	0.043	0.030	0.036	0.044
	(0.057)	(0.057)	(0.058)	(0.058)
Capital Intensity	0.161**	0.160**	0.133	0.113
	(0.082)	(0.079)	(0.086)	(0.085)
Investment assets	0.115	0.131*	0.079	0.107
	(0.084)	(0.077)	(0.084)	(0.079)
Constant	-2.868**	-2.109**	-2.475**	-3.395***
	(1.109)	(1.021)	(1.004)	(0.662)
Year dummies	Yes	Yes	Yes	Yes
Number of Obs	1110	1110	1110	1110
Number of groups	98	98	98	98
Marginal effect	1.258***	0.433***	0.379	1.189***
	(0.337)	(0.147)	(0.355)	(0.396)
	[0.643]	[0.264]	[0.438]	[0.513]

Notes: Hubert-White corrected standard errors in round parentheses and clustered at the industry level in squared brackets.

*, **,*** denote significance at 10%, 5% and 1%, respectively

Wider definition of HT industries HT dummy variable is redefined now to incorporate other activities using intensively ICT industries as suppliers, namely industries 29 (machinery and equipment) and 34 (motor vehicles). Table 3 presents the results for the four regulation proxies. In these regressions, the economy-wide controls that proved to have weak correlation with R&D intensity have been removed. Here again, the main prediction of the Schumpeterian equilibrium is confirmed. The interaction term gives support for a positive and significant impact of regulation on R&D intensity, which is specific for high tech industries. This time however, in the regression using PMR, a negative effect appears in the overall marginal effect (significant only at 10%). In the rest of regressions the significantly positive ME is still observed.

Table 3. Dependent Variable: R&D/VA - Within-group estimates
Alternative definition of high-tech industries (HT2)

	REGIMP	ETCR	PMR	PMR-Public
R&D Spillovers	0.192***	0.193***	0.175***	0.172***
	(0.045)	(0.044)	(0.045)	(0.051)
Regulation	-0.197	0.020	-0.935***	0.127
	(0.129)	(0.071)	(0.248)	(0.274)
Regulation x HT2	1.088***	0.481***	0.568***	1.314***
	(0.167)	(0.070)	(0.114)	(0.362)
Constant	-1.906***	-2.796***	-2.088***	-3.826***
	(0.310)	(0.203)	(0.216)	(0.302)
Year dummies	Yes	Yes	Yes	Yes
Number of Obs	2754	2754	2754	2546
Number of groups	189	189	189	176
Marginal effect	0.891***	0.501***	-0.367*	1.441***
	(0.192)	(0.101)	(0.219)	(0.319)

Notes: Hubert-White corrected standard errors in round parentheses
and clustered at the industry level in squared brackets.
HT2 includes all previously defined HT industries plus
Machinery (24) and Motor Vehicles (34)
*, **,*** denote significance at 10%, 5% and 1%, respectively

Fixed-effect vector decomposition One may also argue that the results presented in the previous section are basically driven by the correlation between R&D intensity and the HT dummy itself. Under this argument, what has been reported as a positive effect of regulation specific to HT industries might merely reflect that HT industries are more R&D intensive. However, notice that what is estimated is the impact of regulation *conditional* on considering only HT industries. As explained in section 3.1, even if HT dummy has been dropped by the within-group transformation, its effect is implicitly controlled by the fixed effect. As an explicit robustness check on this issue, fixed-effect decomposition regressions are run (see Plümper and Troeger, 2007). The methodology consists of three stages. First, a fixed-effect model is estimated in order to obtain a measure of the unobserved fixed heterogeneity. The second stage correlates this residual measure with time-invariant variables, those that are eliminated in the usual within-group strategy. This step then decomposes the fixed effect into a part explained by time-invariant variables and an unexplained one. The third stage re-estimates the model by OLS and includes the unexplained error term accounted in the second step. This final step also controls for collinearity between time-varying and time-invariant variables and it adjusts the degrees of freedom. Results are presented in Table 4. Panel corrected standard errors are reported. After addressing the non-variability of the HT dummy, the positive effect of regulation on HT industries is still supported in relative and absolute terms by the time-varying indicators ETCR and REGIMP. Regressions using these time-varying indicators are more reliable for fixed-effect decomposition because the fixed effect estimated in the first step is less likely to be correlated with them. Accordingly to this, PMR and PMR-Public have been included into the vector of time-invaryng variables. In relative terms (i.e. the interaction) results still hold for PMR and PMR- public. However, the estimated variance of the parameters do not allow to conclude a value different than zero for the ME estimated with these proxies.

Table 4. Dependent Variable: R&D/VA - FEVD

Plümper and Troeger (2007) estimator

	REGIMP	ETCR	PMR	PMR-Public
R&D Spillovers	0.195***	0.196***	0.188***	0.186**
	(0.059)	(0.057)	(0.072)	(0.079)
Regulation	-0.166*	0.019	-0.666***	-0.550***
	(0.090)	(0.090)	(0.027)	(0.010)
Regulation x HT	1.739***	0.715***	0.826**	2.076**
	(0.102)	(0.048)	(0.360)	(0.973)
HT	5.226***	0.466***	0.893***	-0.643***
	(0.015)	(0.012)	(0.060)	(0.062)
eta	1.000***	1.000***	1.000***	1.000***
	(0.002)	(0.002)	(0.002)	(0.005)
Constant	-3.195***	-2.893***	-2.420***	-2.923***
	(0.015)	(0.015)	(0.025)	(0.032)
Year dummies	Yes	Yes	Yes	Yes
Number of Obs	2754	2754	2754	2546
Marginal effect	1.573***	0.734***	0.161	1.526
	(0.083)	(0.058)	(0.350)	(0.975)

Notes: Panel corrected standard errors in parentheses;

*, **,*** denote significance at 10%, 5% and 1%, respectively

3.3.3 A differentiated effect of regulation depending on its level

The results analysed so far are based on the full sample. This section examines if behind these "average" results there is evidence supporting proposition 6. The equilibrium underlying this proposition arises below a certain level of regulation. Here the thread of competition translates into a market structure characterised by an active innovative leader that besides its innovative activities devotes resources to deter its competitors. Contrary to the Schumpeterian equilibrium, here if regulation increases but still not enough to make the economy jump to a continuous replacement, it will reduce the aggregate R&D effort since it will just consume more resources for defensive purposes without altering the power of the leader. Hence, regressions here ask whether it is possible to find a differentiated effect of regulation depending on its level. The only well suited indicator for this exercise is the knock-on effect of regulation (REGIMP) because of its time-series cross-section data structure, that allows to split the sample and to exploit different sources of variations.

Table 5 compares the results for the 10% of country-industries with the lowest level of regulation (first column) with those obtained for the 50% most regulated (second column). Fixed-effect decomposition is used in order to avoid limitations of intra-group variance (see robustness check section). As theoretically expected, when the level of regulation is very low a regressions show a statistic significant change in the sign of estimates. In both absolute and relative terms regressions support the idea of a negative impact of an increase of regulation in already deregulated environments. On the contrary, when the level of regulation is above the median one observes the main type of results exposed above.

Table 5. Dependent Variable: R&D/VA - FEVD
Proxy: Knock-on effect of regulation (REGIMP)

	≤0.1 quantile	> 0.5 quantile
R&D Spillovers	-0.048***	0.184***
	(0.015)	(0.012)
REGIMP	-0.145	-0.733***
	(0.164)	(0.135)
REGIMP x HT	-0.470**	4.153***
	(0.216)	(0.250)
HT	0.714	9.307***
	(0.576)	(0.467)
eta	1.000***	1.000***
	(0.017)	(0.010)
Constant	-4.691***	-5.053***
	(0.434)	(0.242)
Year dummies	Yes	Yes
Number of Obs	476	875
Marginal effect	-0.614***	3.419***
	(0.151)	(0.223)

Note: *, **,*** denote significance at
10%, 5% and 1%, respectively

An alternative way to interpret these findings is under the grid of macro-institutional literature highlighting the diversity of capitalism (see for instance Hall and Soskice 2001; Amable 2003). While offering a variety of topologies and institutional mechanisms, a common point of these works is that there is no such a so-called "best practice" model. On the contrary, different institutional arrangements may lead to what is usually seen as good economic performance. In Table 6 regressions are split considering 5 group of countries: Market-based (US and UK); Social Democratic (Denmark, Finland, and Sweden); Continental Europe (Belgium, France, Germany, Norway, Ireland and Netherlands), Mediterranean Europe (Spain and Italy) and Japan. This typology broadly follows Amable (2003) who identifies these five distinctive models based on factor analysis and clustering over several institutional fields.

In line with the two type of theoretical equilibriums, regressions point out that Market-based countries, characterised by deregulated entrepreneurial environments are in fact economies in which regulation is detrimental to R&D effort. On the other hand, in more coordinated economies such as Continental European countries and Japan, regulation acts as R&D boosting device. No significant results appear for the case of Italy an Spain where most of the variance is explained by country, year and industry fixed effects. Finally, somewhat surprising is the negative correlation between regulation and R&D intensity in Social Democratic countries. These economies are usually seen as opposed to the Anglo-Saxon model. This view is actually true but mainly in terms of welfare state. These countries are, in average, bellow the median value of regulation. They also present some heterogeneity, namely in the second half of the period, where for instance Sweden and Denmark have applied regulatory reforms more intensely (see Conway and Nicoletti, 2006). Hence, these results can be interpreted following the theoretical model: regulation can boost innovative effort, but only after attaining a certain threshold that allows to create a market environment in which defensive strategies are handled.

Table 6 - Dependent Variable: R&D/VA - OLS regressions by group of countries
Proxy: Knock-on effect of regulation (REGIMP)

	MB	SD	CE	ME	JP
R&D Spillovers	0.329***	0.074	-0.067	-0.202	0.187***
	(0.096)	(0.100)	(0.098)	(0.165)	(0.037)
REGIMP	-0.763***	-1.089***	1.212***	0.186	5.043***
	(0.116)	(0.181)	(0.119)	(0.525)	(1.200)
Constant	-4.534***	-6.134***	-2.515***	-6.483***	14.166***
	(0.479)	(0.629)	(0.522)	(0.954)	(2.350)
Year dummies	Yes	Yes	Yes	Yes	Yes
ISIC 2-dig dummies	Yes	Yes	Yes	Yes	Yes
Number of Obs	388	644	1118	396	208

Notes: Hubert-White standard errors in parentheses;
MB: Market-based (US, UK)
SD: Social Democratic (Finland, Sweden, Denmark)
CE: Continental Europe (Belgium, France, Germany,Norway, Ireland, Netherlands)
ME: Mediterranean Europe (Spain and Italy)
JP: Japan
*, **,*** denote significance at 10%, 5% and 1%, respectively

4 Conclusion

This paper has presented in a simple quality-ladders model the consequences of defensive strategies on R&D effort and market structure. Among the multiplicity of available strategies, defensive reactions may increase the cost of R&D beyond the pure technological dynamics. Institutions constraining this set of strategies and reducing the resulting deterring effects may increase the resources devoted to innovation. This effect however is likely to be observed after a certain level of regulation and for big technology jumps. The evolution of R&D expenditure in OECD industries confirms the former results, specially for time-varying indicators of market regulation. In general, regressions provide clear results. In most specifications, regulation positively influences R&D in high-technology industries.

Does the positive correlation between the OECD's indicators of regulation and R&D intensity implies that one should take as "good policies" all those practices covered by these indicators? Of course no, however some of them can positively influence innovation by organising technological competition. Hence, labeling regulation practices as "appropriate" or "inappropriate" for innovation requires a detailed context specification. The message of this paper is to study them in a more neutral way: as rules of the game. Further efforts should be addressed to empirically analyse them with firm demographic data and provide a deeper scrutiny of the model's mechanisms.

A Appendix

A.1 Proofs of theoretical propositions

A.1.1 Proof of proposition 1

The necessity of this condition comes from the fact that any credible commitment of a high R&D effort depends on the capability of the leader to perform, at least, a positive amount of R&D when free entry in research is possible. Equation (11) shows that the leader firm does perform R&D when $\Lambda_L \left[v_L \left(j_\omega + 1 \right) - v_L \left(j_\omega \right) \right] \geq 1$. If free entry applies, then $v_L \left(j_\omega + 1 \right) = \frac{1}{\Lambda_o (j_\omega + 1)} = \frac{\delta (j_\omega + 1)}{h \cos^\xi \theta_{j_\omega}}$. One can obtain $v_L \left(j_\omega \right)$ by adjusting for one step down in the quality-ladder: $v_L \left(j_\omega \right) = \frac{1}{\Lambda_o (j_\omega)} = \frac{\delta (j_\omega + 1) \gamma^{-[\sigma - 1]}}{h \cos^\xi \theta_{j_\omega - 1}}$. Putting these elements together and assuming that $\theta_{j_\omega} = \theta$ yields (12).

To show the sufficiency, observe first the properties of the equilibrium with permanent monopolist. Notice that because of constant returns to scale of the R&D investment, if (12) holds as an strict inequality, the optimal R&D effort for the leader is unbounded. If (12) holds as equality, the leader firm can perform any finite amount of R&D effort. In both cases it can invest in R&D without taking into account outsiders menace. To show this, assume that (12) holds true. The leading position value (11) must be then evaluated for $\ell_o = 0$. The only case ensuring a positive and finite R&D investment of the leader is when:[26]

$$v_L\left(j_\omega+1\right)-v_L\left(j_\omega\right)=\frac{1}{\Lambda_L\left(j_\omega+1\right)} \tag{32}$$

Putting the value of $v_L\left(j_\omega+1\right)$ implied by (32) into (11) (when $\ell_o=0$) yields the present optimal value of a permanent monopolist leader written in equation (13). At equilibrium, the interest rate must verify (32), otherwise the leader carries out zero R&D effort or an unbounded amount. Using the monopolist profits equation (6) and (13), one obtains the interest rate expressed in (14).

It should be proven now that this equilibrium, obtained when the credibility condition (12) holds, is not a profitable outcome for outsiders. Consider equation (10). The self-selection of outsiders in R&D races requires

$$v_L\left(j_\omega+1\right)<\frac{1}{\Lambda_o\left(j_\omega+1\right)} \tag{33}$$

Using the optimal value $v_L\left(j_\omega+1\right)$ stated in (13), profits (6) and the definition of $\Lambda_o\left(j_\omega+1\right)$ gives:

$$\frac{\delta\left(j_\omega+1\right)-\Theta}{\left[1-\gamma^{-[\sigma-1]}\right]}<\frac{\delta\left(j_\omega+1\right)}{\cos^{\xi}\theta} \tag{34}$$

where $\Theta\equiv\frac{c(\theta,\psi)}{\frac{p-1}{p}\frac{EL}{Q}}>0$.

This self-selection condition is indeed implied by the credibility condition (12). To see it, multiply both sides of (12) by $\delta\left(j_\omega+1\right)>0$ to obtain:

$$\frac{\delta\left(j_\omega+1\right)}{\left[1-\gamma^{-[\sigma-1]}\right]}\leq\frac{\delta\left(j_\omega+1\right)}{\cos^{\xi}\theta}$$

Since $\Theta>0$, the fulfillment of (12) then verifies:[27]

$$\frac{\delta\left(j_\omega+1\right)-\Theta}{\left[1-\gamma^{-[\sigma-1]}\right]}<\frac{\delta\left(j_\omega+1\right)}{\left[1-\gamma^{-[\sigma-1]}\right]}\leq\frac{\delta\left(j_\omega+1\right)}{\cos^{\xi}\theta} \tag{35}$$

Thus, if the leader is credible outsiders will not carry out R&D. This establishes proposition 1.■

---

[26] Klette and Griliches (2000) in their Appendix A argue that the leader R&D investment in the closely-related model of Barro and Sala-i-Martin (1995) do not satisfy the second order condition of optimality. Here, when maximising the RHS of the corresponding Bellman equation, the leader investment is derived using a standard CRS-equilibrium rationale as, by construction, one does not deal with a concave objective fonction.

[27] Notice that from (32) the equilibrium with permanent monopolist happens when the credibility condition holds as equality. Since the RHS inequality in (35) is unambigously strict, the self-selection condition will still be satisfied.

A.1.2 Proof of proposition 2

By the maximum principle, the choice of θ_{j_ω},is determined by the first order condition of the RHS of (16). To compute it, use $c\left(\theta_{j_\omega},\psi\right)$ as defined by (8). This gives:

$$\cos^{\xi+\psi}\theta_{j_\omega} = \frac{\psi f}{\xi I_{0L} v_L\left(j_\omega\right)\Lambda_L\left(j_\omega\right)}$$

Recall that the free entry condition in the previous R&D race (the one that the incumbent has won) states: $v_L\left(j_\omega\right) = \frac{1}{\Lambda_o(j_\omega)} = \frac{1}{\Lambda_L(j_\omega)\cos^{\xi}\theta_{j_\omega-1}}$. After applying this, the first order condition can be written as

$$\cos\theta_{j_\omega} = \cos^{\frac{\xi}{\xi+\psi}}\theta_{j_\omega-1}\left[\frac{\psi f}{\xi I_{0L}}\right]^{\frac{1}{\xi+\psi}}$$

Define now $k \equiv \left(\frac{\psi f}{\xi I_{0L}}\right)^{\frac{1}{\xi+\psi}}$; $\beta \equiv \frac{\xi}{\xi+\psi} < 1$; $a_{j_\omega} \equiv \cos\theta_{j_\omega}$. The sequence of $a_{j_\omega} = k\ a^{\beta}_{j_\omega-1}$can be expressed as $a_{j_\omega} = k^{\eta(j_\omega)}$ where $\eta\left(j_\omega\right) = \sum_{j=0}^{j_\omega}\beta^j$ is a geometric series that converges towards $\frac{1}{1-\beta}$. Thus, for a high enough level of j_ω, one has $a = k^{\frac{1}{1-\beta}}$. Putting back the definitions of a, k and β gives directly (17).

Appropriate second-order condition on the RHS of (16) requires:

$$\frac{H}{2\Lambda_L\left(j_\omega\right)\cos^{\psi+2}\theta_{j_\omega}} < 0$$

where $H \equiv I_{oL}\Lambda_L\left(j_\omega\right)v_L\left(j_\omega\right)\xi\cos^{\xi+\psi}\theta_{j_\omega}\left[2-\xi+\xi\cos 2\theta_{j_\omega}\right] + f\psi\left[-2-\psi+\psi\cos 2\theta_{j_\omega}\right]$. By simple inspection, one notices that the second term in brackets is negative (since $\psi > \psi\cos 2\theta_{j_\omega}$). Therefore, a sufficient condition for H be negative is that $2-\xi+\xi\cos 2\theta_{j_\omega} < 0$. After using the identity $\cos 2\alpha = 2\cos^2\alpha - 1$, observe that this happens when $\frac{1}{[1-\cos^2\theta]} < \xi$. Given the solution of the first-order condition, this is implicitly ensured when ξ is sufficiently high.

A.1.3 Proof of proposition 4

The threshold $\overline{\psi}$ is the one solving $\cos^{\xi}\theta = \left[1-\gamma^{-[\sigma-1]}\right]$. Denote $\Omega\left(\psi\right) \equiv \cos^{\xi}\theta = \left[\frac{[\gamma^{\sigma-1}-1]\psi f}{\xi n}\right]^{\frac{\xi}{\psi-\xi}}$ and $\Phi \equiv \left[1-\gamma^{-[\sigma-1]}\right]$. To prove proposition 4, it suffices to show that $\Omega\left(\psi\right)$ intercepts Φ once for $\cos\theta \in \left]0;1\right]$. Taking appropriate derivative gives:

$$\frac{\partial\Omega\left(\psi\right)}{\partial\psi} = \frac{-\xi}{\psi\left[\xi-\psi\right]^2}\left[\frac{\left[\gamma^{\sigma-1}-1\right]\psi f}{\xi n}\right]^{\frac{\xi}{\psi-\xi}}\left[\xi-\psi+\psi\ln\left(\frac{\left[\gamma^{\sigma-1}-1\right]\psi f}{\xi n}\right)\right]$$

Using the expression for $\cos\theta$, $\frac{\partial\Omega(\psi)}{\partial\psi}$ reduces to:

$$\frac{\partial\Omega\left(\psi\right)}{\partial\psi}=\frac{-\xi\cos^{\xi}\theta}{\psi\left[\xi-\psi\right]}\left[1-\psi\ln\left(\cos\theta\right)\right]$$

Moreover,

- Since $\psi>\xi$ then$\frac{-\xi\cos^{\xi}\theta}{\psi[\xi-\psi]}>0$
- Since $\cos\theta\in\left]0;1\right]$ then $1-\psi\ln\left(\cos\theta\right)>0$

Thus $\frac{\partial\Omega(\psi)}{\partial\psi}>0$,which means that $\Omega\left(\psi\right)$ is a monotonically increasing function of ψ. Furthermore, for $\gamma>1$ and $\sigma>1$ one verifies that $\Phi<1$. Hence, for relevant values of $\cos\theta$ there exists a unique intercept between Ω and Φ. ■

A.1.4 Proof of proposition 5

By simple inspection of (27) one verifies that $s_r\ (\psi)$is increasing in ψ . Analytically, using price setting $p=\gamma$ and (27), the effect of ψ on s_r is:

$$\frac{ds_r}{d\psi}=\frac{n^2\left[\gamma-1\right]\gamma^{2+\sigma}\xi}{\left\{\gamma^{\sigma}\psi\left[n\left[\gamma-1\right]+\rho\right]+\gamma\left[n\left[\gamma\xi+\psi\right]-\rho\psi\right]\right\}^2}>0$$

Notice that s_r is a concave function of ψ.

$$\frac{d^2s_r}{d\psi^2}=\frac{-2n^2\left[\gamma-1\right]\gamma^{2+\sigma}\xi\left\{\gamma\left[n-\rho\right]+\gamma^{\sigma}\left[n\left[\gamma-1\right]+\rho\right]\right\}}{\left\{\gamma^{\sigma}\psi\left[n\left[\gamma-1\right]+\rho\right]+\gamma\left[n\left[\gamma\xi+\psi\right]-\rho\psi\right]\right\}^3}<0$$

It is easy to see that the term in braces in the numerator is positive since $\rho\gamma^{\sigma}>\rho\gamma$. The same remark applies to the denominator. Hence $\frac{d^2s_r}{d\psi^2}<0$ meaning that s_r is concave on ψ for any possible value of the size of innovation $\left(\gamma>1\right)$. An envelope-theorem rationale can be applied. Observing that, as ψ increases, the function $s_r\left(\psi\right)$ converges asymptotically towards its maximum $\overline{s_r}\left(\gamma\right)=\lim\limits_{\psi\to\infty}sr(\psi)=\frac{n[\gamma-1]\gamma^{\sigma}}{n[\gamma-\gamma^{\sigma}+\gamma^{\sigma+1}]+\rho[\gamma^{\sigma}-\gamma]}$. If $\frac{d\overline{s_r}(\gamma)}{d\gamma}>0$ then the shape of $s_r\left(\psi\right)$ is positively affected by γ. To verify this, take partial derivatives.

$$\frac{d\overline{s_r}\left(\gamma\right)}{d\gamma}=\frac{n\gamma^{\sigma}\left\{\gamma^{\sigma}\rho+\left[n-\rho\right]\left[1+\sigma\left[\gamma-1\right]\right]\right\}}{\left\{\gamma\left[n-\rho\right]+\gamma^{\sigma}\left[n\left[\gamma-1\right]+\rho\right]\right\}^2}$$

The sign of this expression depends crucially on the sign of the braces in the numerator. If $n>0$ the sufficient condition for $\frac{d\overline{s_r}(\gamma)}{d\gamma}>0$ is that $G\left(\gamma\right)\equiv\gamma^{\sigma}-1-\sigma\left[\gamma-1\right]\geq0$. Since $\frac{dG(\gamma)}{d\gamma}=\sigma\left[\gamma^{\sigma-1}-1\right]>0$ and $G\left(1\right)=0$, G is a continuous monotonically increasing function of

γ that is positive for any value of $\gamma \in]1, \infty[$. Hence the slope of $s_r(\psi)$ increases with the size of innovation.■

A.1.5 Proof of proposition 5

Analysing the effect of ψ on $s_{rm}(\psi)$:

$$\frac{ds_{rm}(\psi)}{d\psi} = \frac{f\left[1-\gamma^{-(\sigma-1)}\right]^{1-\frac{\psi}{\xi}} \ln\left[1-\gamma^{-(\sigma-1)}\right]}{n\xi\left[1+\frac{f}{n}\left[1-\gamma^{-(\sigma-1)}\right]^{1-\frac{\psi}{\xi}}+\frac{\rho}{n[\gamma-1]}\right]}$$

Since $0 < 1-\gamma^{-(\sigma-1)} < 1$ it follows that $\frac{ds_{rm}}{d\psi} < 0$.Thus, s_{rm} is decreasing in ψ.■

A.2 Sample summary

List of countries: Belgium; Denmark; Finland; France; Germany; Ireland; Italy; Japan; Netherlands; Norway; Spain; Sweden; UK; US

Table A1 - List of industries

ISIC Rev 3 Code	Industry
15-16	Food products, beverages and tobacco
17-19	Textiles, textile products, leather and footwear
17	Textiles
18	Wearing apparel, dressing and dyeing of fur
19	Leather, leather products and footwear
20	Wood and products of wood and cork
21-22	Pulp, paper, paper products, printing and publishing
24	Chemicals and chemical products
25	Rubber and plastics products
26	Other non-metallic mineral products
27	Basic metals
28	Fabricated metal products, except machinery and equipment
29	Machinery and equipment, n.e.c.
30	Office, accounting and computing machinery
31	Electrical machinery and apparatus, nec
32	Radio, television and communication equipment
33	Medical, precision and optical instruments, watches and clocks
34	Motor vehicles, trailers and semi-trailers

Table A2 - Descriptive statistics

Variable	Number of Obs.	Mean	Std. Dev.	Std. Dev./Mean
R&D / Value-added	2850	0,09	0,17	1,89
PMR	5760	1,80	0,44	0,24
PMR-Public	6375	3,01	1,28	0,42
ETCR	6375	4,19	1,31	0,31
REGIMP	6375	0,13	0,04	0,28
Proximity to the frontier	6099	56,89	24,07	0,42
Capital Intensity	2785	0,05	0,03	0,68
Financial assets/GDP	4440	66,91	50,33	0,75

References

[1] Aghion, P., Howitt, P., 1992. A model of growth through creative destruction. Econometrica. Vol. 60, No. 2, pp. 353-35.

[2] Aghion, P., Bloom, N., Blundell, R. , Griffith, R., Howitt, P. , 2005. Competition and Innovation: An Inverted U Relationship. Quarterly Journal of Economics, pp. 701-728.

[3] Albert, M., 1991. Capitalisme contre capitalisme. Paris. Seuil.

[4] Amable, B., 2003. The Diversity of Modern Capitalism. Oxford. Oxford University Press.

[5] Amable, B., Demmou, L., Ledezma, I., 2009. Product Market Regulation, Innovation and Distance to Frontier. Forthcomming in Industrial and Corporate Change.

[6] Arnold, J., Nicoletti, G., Scarpetta, S., 2008. Regulation, Allocative Efficiency and Productivity in OECD Countries: Industry and Firm-Level Evidence, OECD Economics Department Working Papers, No. 616, OECD Publishing.

[7] Bain, J., 1949. A Note on Pricing in Monopoly and Oligopoly. American Economic Review. 39, pp. 448-64.

[8] Chandler, A., 1990. Scale and Scope: The Dynamics of Industrial Enterprise. Cambridge, MA. The Belknap Press of Harvard University Press.

[9] Cohen, W., Nelson, R., Walsh, J., 2002. Protecting their intellectual assets: appropriability conditions and why US manufacturing firms patent (or not). NBER Working Paper no. 7552.

[10] Cohen W., Goto, A., Nagata, A., Nelson, R., Walsh, J., 2002. R&D spillover, patents and the incentives to innovate in Japan and the United States. Research Policy/ vol. 31, pp. 1349-1367.

[11] Conway, P., Nicoletti, G., 2006. Product Market regulation in the Non-Manufacturing Sector of OECD Countries: Measurements and Highlights. OECD Economics Department Working Paper No. 530, Paris: OECD.

[12] Conway, P., Janod, V., Nicoletti, G., 2006. Product Market Regulation in OECD Countries: 1998 to 2003. Economics Department. Working Papers No. 419, Paris: OECD.

[13] Conway P., de Rosa, D., Nicoletti, G., Steiner, F., 2006. Regulation, Competition, and Productivity Convergence. Economics Department Working Papers No. 509, Paris: OECD.

[14] Crépon, B., Duguet, E., 1997. Research and development, competition and innovation. Pseudo-maximum likelihood and simulated maximum likelihood methods applied to count data models with heterogeneity. Journal of Econometrics. Vol. 79, No. 2, pp. 355-378.

[15] Dasgupta, P., Gilbert, R., Stiglitz, J., 1982. Invention and Innovation Under Alternative Market Structures: The Case of Natural Resources. The Review of Economic Studies, Vol. 49, No. 4, pp. 567-582.

[16] Denicolò, V., 2001. Growth with Non-Drastic Innovations and the Persistence of Leadership. European Economic Review, Vol. 45, No 8, pp. 1399-1414.

[17] De Serres, A., Kobayakawa, S., Sløk, T., Vartia, L., 2006. Regulation of Financial Systems and Economic Growth. OECD Economics Department Working Papers, No. 506

[18] Dinopoulos, E., Sener, F., 2007. New direction in schumpeterian growth theory. Forthcoming in Horst Hanusch and Andreas Pyka (eds.), Elgar Companion to Neo-Schumpeterian Economics, Edward Elgar, Cheltenham.

[19] Dinopoulos, E., Syropoulos, C. , 2007. Rent protection as a barrier to innovation and growth. Economic Theory. Vol. 32, No. 1, pp. 309-332.

[20] Etro, F., 2007. Competition, Innovation, and Antitrust. A Theory of Market Leaders and Its Policy Implications. Berlin: Springer Verlag.

[21] Etro, F., 2008. Stackelberg Competition with Endogenous Entry. Economic Journal, Vol. 118 No. 4, 1670-1697.

[22] Gilbert, R., Newbery, D., 1982. Preemptive Patenting and the Persistence of Monopoly. The American Economic Review, Vol. 72, No. 3, pp. 514-526

[23] Griffith, R., Harrison, R., Simpson, H., 2006. Product Market Reform and Innovation in the EU. CEPR Discussion Papers 5849.

[24] Grossman, G., Helpman, E., 1991a. Quality Ladders in the theory of growth. Review of Economic Studies. Vol. 58, No. 1, pp. 43-61.

[25] Grossman, G., Helpman, E., 1991b. Quality Ladders and Product Cycles. The Quarterly Journal of Economics. Vol. 106, No. 2, pp 557-586.

[26] Grossmann, V., Steger, T., 2008. Anti-competitive Conduct, In-house R&D, and Growth. European Economic Review, Vol. 52, pp. 987–1008.

[27] Hall, P., Soskice, D., (Eds) 2001. Varieties of Capitalism: The Institutional Foundations of Comparative Advantage. Oxford. Oxford University Press.

[28] Inklaar, R., Timmer, M., van Ark, B., 2008. Market services productivity across Europe and the US. Economic Policy, No. 1, pp. 139–19

[29] Jones, C., 1995. Time series tests of endogenous growth models. Quarterly Journal of Economics, Vol. 110, pp. 495-525.

[30] Klette, J., Griliches, Z., 2000. Empirical Patterns of Firm Growth and R&D Investment: A Quality Ladder Model Interpretation. The Economic Journal, Vol. 110, No. 463, pp. 363-387.

[31] Levin, R., Klevorick, A., Nelson, R., Winter, S., 1987. Appropriating the returns from industrial R&D. BrookingsPapers on Economic Activity. pp. 783–820.

[32] Li, C., 2003. Endogenous growth without scale effects: comment. The American Economic Review. Vol. 93, No. 3., pp. 1009-1017.

[33] Malerba, F., Orsenigo, Peretto, P., 1997. Persistence of Innovative Activities, Sectoral Patterns of Innovation and International Technological Specialization. International Journal of Industrial Organization, 15, 801-26.

[34] Nicoletti, G., Scarpetta, S., 2003. Regulation, productivity and growth: OECD evidence. Economic Policy Vol. 36, pp. 9-72.

[35] Plümper, T., Troeger, V., 2007. Efficient estimation of time-invariant and rarely changing variables in finite sample panel analyses with unit fixed effects. Political Analysis, Vol. 15, No. 2, pp. 124-139.

[36] Reinganum, J., 1982. Uncertain Innovation and the Persistence of Monopoly. The American Economic Review, Vol. 73, No. 4, pp. 741-748.

[37] Rivking, J., 2001. Reproducing Knowledge: Replication without Imitation at Moderate Complexity. Organization Science, Vol. 12, No. 3, pp. 274-293.

[38] Salop, S., 1977. Strategic Entry Deterrence. The American Economic Review, Vol. 69, No. 2, pp. 335-338

[39] Segerstrom, P., 1998. Endogenous growth without scale effects. The American Economic Review. Vol. 88, No. 5., pp. 1290-1310.

[40] Segrestrom, P., Zolnierek, J., 1999. The R&D Incentives of Industry Leaders. International Economic Review. Vol. 40, No. 3., pp. 745-766.

[41] Segrestrom, P., 2007. Intel Economics. International Economic Review. Vol. 93, No. 3., pp. 709-728.

[42] Tingvall, P., Poldahl, A., 2006. Is There Really an Inverted U-shaped Relation Between Competition and R&D?. Economics of Innovation and New Technology, Vol. 15, No. 2, pp. 101-118.

[43] Thoenig, M., Verdier, T., 2003. A theory of defensive skill-biased innovation and globalization. The American Economic Review. Vol. 93, No. 3., pp. 709-728.

[44] Williamson, O., 1963. Selling Expense as a Barrier to Entry. Quarterly Journal of Economics, Vol. 77, pp. 112–128.

[45] Young, A., 1998. Growth without scale effects. Journal of Political Economy. Vol. 106, No. 1, pp. 41-63.