Innovation and Growth:
The Schumpeterian Perspective

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1 Introduction

There is a broad consensus among most European leaders and in Brussels on the importance of structural reforms to foster innovation-based growth in Europe. However, this consensus has not reached the European public at large. One recent example is France, where the timid reforms proposed by the Economy Minister have met opposition from all political parties. So often do we hear that structural reforms amount to austerity, and therefore are detrimental to growth and employment. Similarly, a commonly held view is that going for supply side policies (structural reforms or fiscal devaluations aimed at fostering such reforms) necessarily means that we have decided to ignore the demand side. We also hear that a fiscal system conducive to innovation and entrepreneurship would necessarily aggravate inequality and reduce social mobility. The purpose of this survey is twofold: first, to bring the reader up to speed with recent research in the Economics of Innovation and Growth; second, to provide the reader with theoretical and empirical background to think about growth policy design in EU countries.

We should emphasize right away that this survey is opinionated in the sense that it reflects our own biases and uses the lenses of our own work. However, the reader should feel free (and is welcome) to disagree and take issue with the models, analyses and statements outlaid in the next sections. Our main purpose is indeed to encourage debates and criticisms and to inspire future work on the subject, in particular contributions that involve creative destruction of our own work.

In particular, we will propose some answers to questions such as:

1. What distinguishes innovation-led growth from other types of growth? What are the main drivers of innovation-led growth? (Why) is innovation necessary for sustained long-run growth? What are the main levers that governments should activate to promote innovation-led growth?

2. Why do we need competition policy for innovation-led growth? Should that lead us to dispense with patent protection: in other words, should we oppose patent protection and competition as potential drivers of innovation-led growth? Similarly, should the need for competition policy lead us to reject any form of sectoral (or industrial) policy?

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3. How should we reform the welfare state in order to facilitate the transition from imitation-based (or catch-up) growth and innovation-led growth? Should the state simply concentrate on "regalian" functions, i.e. law and order, education and health?

4. Should EU governments rely more on aggregate demand or on competitiveness to foster growth? Should we oppose structural reforms and the need for (more flexible) macroeconomic policy in enhancing growth in Europe? And how can macroeconomic policy and macro prudential regulations affect innovation-led growth?

5. Should governments subsidize R&D to foster innovation-led growth: is such government intervention necessary or sufficient? How should we design the tax system to make growth more "inclusive" and reconcile innovation-led growth with the need to foster social mobility and to avoid excessive inequality? Can public subsidies always make up for a more expropriatory taxation?

6. What are the limits to patenting and intellectual property and why do we need academic freedom and openness?

The remaining part of this survey will be organized as follows. Section 2 will argue that Schumpeterian growth theory provides a relevant framework in which to analyze key aspects of innovation-led growth and to also think about growth policy design. We will contrast the predictions and policy recommendations that come out of that theory from those delivered by other growth theories (in particular the so-called AK model, and the product variety model). Section 3 discusses growth policy design. In particular, building on the previous two sections, it will draw lessons on how to foster innovation-led growth in the EU. Section 4 touches upon the recent debate on secular stagnation. Section 5 uses the lenses of Schumpeterian growth theory to provide new insights into the design of R&D policy. Section 6 looks at the organization of innovation and the role of academic freedom and openness. Section 7 concludes by suggesting avenues for future research.

2 Looking for growth paradigms to think about growth policy

Today's research on growth economics, with its double objective of improving our understanding of the growth process and of helping us think more systematically about growth policy design, uses essentially four leading growth paradigms.

2.1 The neoclassical growth model

The primary reference in growth economics is the neoclassical paradigm. The success of this model owes first to its parsimony; the growth process is described by only two equations: (i) a production equation that expresses the current flow of output good as a function of the current stocks of capital and labor:

$$Y = AK^\alpha L^{1-\alpha},$$

where A is a productivity parameter and where $\alpha < 1$ so that production involves decreasing returns to capital, and (ii) a law of motion that shows how capital accumulation depends on investment (equal to aggregate savings) and depreciation:

$$\dot{K} = sY - \delta K,$$

where sY denotes aggregate savings and δK denotes aggregate depreciation.

What also makes this model the benchmark for growth analysis is, paradoxically, its implication that, in the long run, economic growth does not depend on economic conditions. In particular, economic policy cannot affect a country's long-run growth rate. Specifically, per capita GDP Y/L cannot grow in the long run unless we assume that productivity A also grows over time, which Solow (1956) refers to as "technical progress". The problem is that in this neoclassical model, technical progress cannot be explained or even rationalized. To analyze policies for growth, one needs a theoretical framework in which productivity growth is endogenous; that is, dependent upon characteristics of the economic environment. That framework must account for long-term technological progress and productivity growth, without which diminishing marginal productivity would eventually choke off all growth.

2.2   The AK model

The first version of endogenous growth theory is the so-called AK theory, which does not make an explicit distinction between capital accumulation and technological progress. In effect it just lumps together the physical and human capital whose accumulation is studied by neoclassical theory with the intellectual capital that is accumulated when technological progress is made. When this aggregate of different kinds of capital is accumulated there is no reason to think that diminishing returns will drag its marginal product down to zero, because part of that accumulation is the very technological progress needed to counteract diminishing returns. According to the AK paradigm, the way to sustain high growth rates is to save a large fraction of GDP, some of which will find its way into financing a higher rate of technological progress and will thus result in faster growth.

Formally, the AK model is the neoclassical model without diminishing returns. The theory starts with an aggregate production function that is linear homogeneous in the stock of capital:

$$Y = AK$$

with A a constant. If capital accumulates according to the same equation:

$$\dot{K} = sY - \delta K$$

as before, then the economy's long-run (and short-run) growth rate is

$$g = sA - \delta.$$

which is increasing in the saving rate s.

AK theory presents a "one size fits all" view of the growth process. It applies equally to countries that are on the leading edge of the world technology frontier and to countries that are far behind. Like the neoclassical model, it postulates a growth process that is independent of developments in the rest of the world, except insofar as international trade changes the conditions for capital accumulation. Yet, it is a useful tool for many purposes when the distinction between innovation and accumulation is of secondary importance.

2.3   The product-variety model

The second wave of endogenous growth theory consists of so-called "innovation-based" growth models, which themselves belong to two parallel branches. One branch is the product variety model of Romer (1990), in which

innovation causes productivity growth by creating new, but not necessarily improved, varieties of products. This paradigm grew out of the new theory of international trade, and emphasizes the role technology spillovers.

It starts from a Dixit-Stiglitz (1977) production function of the form:

$$Y_t = \sum_0^{N_t} K_{it}^\alpha di$$

in which there are N_t different varieties of intermediate product, each produced using K_{it} units of capital. By symmetry, the aggregate capital stock K_t will be divided up evenly among the N_t existing varieties equally, which means we can re-express the production function as:

$$Y_t = N_t^{1-\alpha} K_t^\alpha.$$

According to this function, the degree of product variety N_t is the economy's aggregate productivity parameter, and its growth rate is the economy's long-run growth rate of per-capita output. Product variety raises the economy's production potential because it allows a given capital stock to be spread over a larger number of uses, each of which exhibits diminishing returns.

The fact that there is just one kind of innovation, which always results in the same kind of new product, means that the product-variety model is limited in its ability to generate context-dependent growth. In particular, the theory makes it difficult to talk about the notion of technology frontier and of a country's distance to the frontier, since all intermediate products are on a technological par. "

Moreover, nothing in this model implies an important role for exit and turnover; indeed increased exit can do nothing but reduce the economy's GDP, by reducing the variety variable N_t that uniquely determines aggregate productivity. Thus there is no role for "creative destruction," the driving force in the Schumpeterian model to be discussed below.

2.4 The Schumpeterian model

The Schumpeterian paradigm (see Aghion and Howitt (1992, 1998)) grew out of modern industrial organization theory and put firms and entrepreneurs at the heart of the growth process. The paradigm relies on three main ideas.

First idea: long-run growth relies on innovations. These can be process innovations, namely to increase the productivity of production factors (e.g. labor or capital); or product innovations (introducing new products); or organizational innovations (to make the combination of production factors more efficient).

Second idea: Innovations result from investments like research and development (R&D), firms' investments in skills, search for new markets,...that are motivated by the prospect of monopoly rents for successful innovators. An important consideration for thinking about the role for public intervention in the growth process, is that innovations generate positive knowledge spillovers (on future research and innovation activity) which private firms do not fully internalize. Thus private firms under laissez-faire tend to underinvest in R&D, training,...This propensity to underinvest is reinforced by the existence of credit market imperfections which become particularly tight in recessions. Hence an important role for the state as a co-investor in the knowledge economy.

Third idea: creative destruction. Namely, new innovations tend to make old innovations, old technologies, old skills, become obsolete. Thus growth involves a conflict between the old and the new: the innovators of

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yesterday resist new innovations that render their activities obsolete. This also explains why innovation-led growth in OECD countries is associated with a higher rate of firm and labor turnover. And it suggests a second role for the state, namely as an insurer against the turnover risk and to help workers move from one job to another. More fundamentally, governments need to strike the right balance between preserving innovation rents and at the same time not deterring future entry and innovation. This is the paradigm that we find most useful, and it plays an especially important role throughout the book. We present it in Chapter 4 and then use it and extend it in the subsequent chapters of the book.

More formally, Schumpeterian theory begins with a production function specified at the industry level:

$$Y_{it} = A_{it}^{1-\alpha} K_{it}^{\alpha}, \qquad 0 < \alpha < 1$$

where A_{it} is a productivity parameter attached to the most recent technology used in industry i at time t. In this equation, K_{it} represents the flow of a unique intermediate product used in this sector, each unit of which is produced one-for-one by final output or, in the most complete version of the model, by capital. Aggregate output is just the sum of the industry-specific outputs Y_{it}.

Each intermediate product is produced and sold exclusively by the most recent innovator. A successful innovator in sector i improves the technology parameter A_{it} and is thus able to displace the previous product in that sector, until it is displaced in turn by the next innovator. Thus a first implication of the Schumpeterian paradigm, is that *faster growth generally implies a higher rate of firm turnover, because this process of creative destruction generates entry of new innovators and exit of former innovators.*

A first distinct prediction of Schumpeterian Growth Theory is therefore:

Prediction 1: *The turnover rate is positively correlated with the productivity growth rate.*

Another distinctive implication of the model is that *innovation-led growth may be excessive under laissez-faire.* Growth is excessive (resp. insufficient) under laissez-faire when the business-stealing effect associated with creative destruction dominates (resp. is dominated by) the intertemporal knowledge spillovers from current to future innovators.[1]

3 Some main applications of Schumpeterian growth theory

3.0.1 Growth meets IO

Both, empirical studies[2] and casual evidence point to a positive correlation between growth and product market competition which is at odds with what most growth models predict. The Solow and AK models assumes perfect competition, thus by construction they cannot look at how growth is affected by changes in the degree of product market competition. In the product variety model, more product market competition corresponds to a higher degree of substitutability α between intermediate inputs, and therefore to lower rents for potential innovators. This in turn has a detrimental effect on R&D and therefore on growth.

While in Aghion and Howitt (1992)' model also, more competition discourages innovation and growth, yet one can reconcile theory with evidence by allowing for *step-by-step innovation* in the Schumpeterian growth paradigm.[3] Namely, a firm that is currently behind the technological leader in the same sector or industry must

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[1]Which of these effects dominates will depend in particular upon the size of innovations. Assessing the relative importance of these two effects in practice, requires estimating the structural parameters of the growth model using micro data (see footnote 9).

[2]E.g. see Blundell, Griffith and Van Reenen (1995).

[3]See Aghion, Harris and Vickers (1997) and Aghion, Harris, Howitt and Vickers (2001).

catch up with the leader before becoming a leader itself. This step-by-step assumption implies that firms in some sectors will be *neck-and-neck.* In turn in such sectors, increased product market competition, by making life more difficult for neck-and-neck firms, will encourage them to innovate in order to acquire a lead over their rival in the sector. This we refer to as the *escape competition effect.* On the other hand, in *unleveled* sectors where firms are not neck-and-neck, increased product market competition will tend to discourage innovation by laggard firms as it decreases the short-run extra profit from catching up with the leader. This we call the *Schumpeterian effect.* Finally, the steady-state fraction of neck-and-neck sectors will itself depend upon the innovation intensities in neck-and-neck versus unleveled sectors. This we refer to as the *composition effect.*

The Schumpeterian growth framework with step-by-step innovation, generates three interesting predictions:

Prediction 1: *The relationship between competition and innovation follows an inverted-U pattern.*

Intuitively, when competition is low, innovation intensity is low in neck and neck sectors, therefore most sectors in the economy are neck and neck (the composition effect); but precisely it is in those sectors that the escape competition effect dominates. Thus overall aggregate innovation increases with competition at low levels of competition. When competition is high, innovation intensity is high in neck and neck sectors, therefore most sectors in the economy are unleveled sectors, so that the Schumpeterian effect dominates overall. This inverted-U prediction is confirmed by Aghion, Bloom, Blundell, Griffith and Howitt (2005), using panel data on UK firms.

Prediction 2: *More intense competition enhances innovation in "frontier" firms but may discourage it in "non-frontier" firms.*

Intuitively, a frontier firm can escape competition by innovating, unlike a non-frontier firm who can only catch up with the leader in its sector. This prediction is tested by Aghion, Blundell, Griffith, Howitt and Prantl (2009) using again panel data of UK firms.

Prediction 3: *There is complementarity between patent protection and product market competition in fostering innovation.*

Intuitively, competition reduces the profit flow of non-innovating neck-and-neck firms, whereas patent protection is likely to enhance the profit flow of an innovating neck-and-neck firm. Both contribute to raising the net profit gain of an innovating neck-and-neck firm; in other words, both types of policies tend to enhance the escape competition effect.[4] This prediction is confirmed by Aghion, Howitt and Prantl (2013) using OECD country-industry panel data. This prediction cannot be generated by the product variety model where competition can only counteract the effects of better patent protection (the former reduces innovation rents whereas the latter enhances those rents).

3.0.2 Schumpeterian growth and firm dynamics

The empirical literature has documented various stylized facts on firm size distribution and firm dynamics using micro firm-level data. In particular: (*i*) the firm size distribution is highly skewed; (*ii*) firm size and firm age are highly correlated; (*iii*) small firms exit more frequently, but the ones that survive tend to grow faster than the average growth rate.

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[4]That competition and patent protection should be complementary in enhancing growth rather than mutually exclusive is at odds with Romer's (1990) product variety model, where competition is always detrimental to innovation and growth (as we discussed above) for exactly the same reason that intellectual property rights (IPRs) in the form of patent protection are good for innovation: namely, competition reduces post-innovation rents, whereas patent protection increases these rents. See Acemoglu and Akcigit (2012) for a general analysis of optimal patent protection in Schumpeterian models with step-by-step innovation.

These are all facts that non-Schumpeterian growth models cannot account for. In particular, the first four facts listed require a new firm to enter, expand, then shrink over time, and eventually be replaced by new entrants: these and the last fact on the importance of reallocation are all embodied in the Schumpeterian idea of *creative destruction*.[5]

Instead the Schumpeterian model by Klette and Kortum (2004) can account for these facts. This model adds two elements to the baseline model: first, innovations come from both entrants and incumbents; second, firms are defined as a collection of production units where successful innovations by incumbents will allow them to expand in product space.[6]

This model allows us to explain the above stylized facts:

Prediction 1: *The size distribution of firms is highly skewed.*

Recall that in this model, firm size is summarized by the number of product lines of a firm. Hence, a firm needs to have succeeded many attempts to innovate in new lines and at the same survived many attempts by potential entrants and other incumbents at taking over its existing lines, in order to become a large firm. This is turn explains why there are so few very large firms in steady-state equilibrium, i.e. why firm size distribution is highly skewed as shown in a vast empirical literature.

Prediction 2: *Firm size and firm age are positively correlated.*

In the model, firms are born with a size of 1. Subsequent successes are required for firms to grow in size, which naturally produces a positive correlation between size and age. This regularity has been documented extensively in the literature.[7]

Prediction 3: *Small firms exit more frequently. The ones that survive tend to grow faster than average.*

In the above model, it takes only one successful entry to make a one-product firm to exit, whereas it takes two successful innovations by potential entrants to make a two-product firm exit. The facts that small firms exit more frequently and grow faster conditional on survival have been widely documented in the literature.[8]

3.0.3   Growth meets development

The previous two sections have implications for how Schumpeterian growth theory can help bridge the gap between growth and development economics: first, by capturing the idea that growth-enhancing policies or institutions vary with a country's level of technological development; second, by analyzing how institutional development (or the lack of it) affects firm size distribution and firm dynamics.

Appropriate institutions   In Section 3.1 above we mentioned some recent evidence for the prediction that competition and free-entry should be more growth-enhancing in more frontier firms, which implies that they should be more growth-enhancing in more advanced countries since those have a larger proportion of frontier firms. This idea can be extended to other aspects of growth policy design. Indeed, the Schumpeterian paradigm is flexible in modeling the contribution of past innovations. It encompasses the case of an innovation that leapfrogs the best technology available before the innovation, resulting in a new technology parameter A_{it} in

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[5]In the product variety model, exit is always detrimental to growth as it reduces product variety.

[6]Various versions of this framework have been estimated using micro-level data by Lentz and Mortensen (2008), Acemoglu, Akcigit, Bloom and Kerr (2013), Akcigit and Kerr (2014) and Garcia-Macia, Hsieh and Klenow (2014).

[7]For recent discussions, see Haltiwanger, Jarmin and Miranda (2010) and Akcigit and Kerr (2010).

[8]See Aghion, Akcigit and Howitt (2014 a,b) and Akcigit and Kerr (2010) for references. In a recent work, Acemoglu, Akcigit, Bloom and Kerr (2013) analyze the effects of various industrial policies on equilibrium productivity growth, including entry subsidy and incumbent R&D subsidy, in an enriched version of the above framework.

the innovating sector i, which is some multiple γ of its pre-existing value. And it also encompasses the case of an innovation that catches up to a global technology frontier $\overline{A}_t$ which we typically take to represent the stock of global technological knowledge available to innovators in all sectors of all countries. In the former case the country is making a leading-edge innovation that builds on and improves the leading edge technology in its industry. In the latter case the innovation is just implementing (or imitating) technologies that have been developed elsewhere.

For example, consider a country in which in any sector leading edge innovations take place at the frequency μ_n and implementation innovations (or imitations) take place at the frequency μ_m. Then the change in the economy's aggregate productivity parameter A_t will be:

$$A_{t+1} - A_t = \mu_n \left(\gamma - 1\right) A_t + \mu_m \left(\overline{A}_t - A_t\right)$$

and hence the growth rate will be:

$$g_t = \frac{A_{t+1} - A_t}{A_t} = \mu_n \left(\gamma - 1\right) + \mu_m \left(a_t^{-1} - 1\right) \tag{1}$$

where:

$$a_t = A_t/\overline{A}_t$$

is an inverse measure of "distance to the frontier."

Thus, by taking into account that innovations can interact with each other in different ways in different countries Schumpeterian theory provides a framework in which the growth effects of various policies are highly context-dependent. In particular, the Schumpeterian apparatus is well suited to analyze *how a country's growth performance will vary with its proximity to the technological frontier a_t, to what extent the country will tend to converge to that frontier, and what kinds of policy changes are needed to sustain convergence as the country approaches the frontier.*

We could take as given the critical innovation frequencies μ_m and μ_n that determine a country's growth path as given, just as neoclassical theory often takes the critical saving rate s as given. However, Schumpeterian theory goes deeper by deriving these innovation frequencies endogenously from the profit-maximization problem facing a prospective innovator, just as the Ramsey model endogeneizes the savings rate s by deriving it from household utility maximization. This maximization problem and its solution, will typically depend upon institutional characteristics of the economy such as property right protection, the financial system,...and also upon government policy; moreover, the equilibrium intensity and mix of innovation will often depend upon institutions and policies in a way that varies with the country's distance to the technological frontier a.

Equation (1) incorporates Gerschenkron's (1962) "advantage of backwardness," in the sense that the further the country is behind the global technology frontier (i.e., the smaller is a_t) the faster it will grow, given the frequency of implementation innovations. As in Gerschenkron's analysis, the advantage arises from the fact that implementation innovations allow the country to make larger quality improvements the further it has fallen behind the frontier. As we shall see below, this is just one of the ways in which distance to the frontier can affect a country's growth performance.

In addition, growth equations like (1) make it quite natural to capture Gerschenkron's idea of "appropriate institutions"[9]. Suppose indeed that the institutions that favors implementation innovations (that is, that lead to firms emphasizing μ_m at the expense of μ_n) are not the same as those that favor leading-edge innovations

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[9] See Acemoglu-Aghion-Zilibotti (2006) for a formalization of this idea.

(that is, that encourage firms to focus on μ_n): then, far from the frontier a country will maximize growth by favoring institutions that facilitate implementation, however as it catches up with the technological frontier, to sustain a high growth rate the country will have to shift from implementation-enhancing institutions to innovation-enhancing institutions as the relative importance of μ_n for growth is also increasing.

Thus Acemoglu, Aghion and Zilibotti (2006), henceforth AAZ, provide support to the following predictions using a cross-country panel of more than 100 countries over the 1960-2000 period:

Prediction 1: *Average growth should decrease more rapidly as a country approaches the world frontier when openness is low.*

AAZ repeat the same exercise using entry costs faced by new firms instead of openness. They show:

Prediction 2: *High entry barriers become increasingly detrimental to growth as the country approaches the frontier.*

These two empirical exercises point to the importance of interacting institutions or policies with technological variables in growth regressions: openness is particularly growth-enhancing in countries that are closer to the technological frontier; entry is more growth-enhancing in countries or sectors that are closer to the technological frontier.

Next, to the extent that frontier innovation makes greater use of research education than imitation, the prediction is:

Prediction 3: *The more frontier an economy is, the more growth in this economy relies on research education.*[10]

Finally, one can look at the relationship between technological development, democracy and growth. An important channel is Schumpeterian: namely, democracy reduces the scope for expropriating successful innovators or for incumbents to prevent new entry by using political pressure or bribes: in other words, democracy facilitates creative destruction and thereby encourages innovation.[11] To the extent that innovation matters more for growth in more frontier economies, the prediction is:

Prediction 4: *The correlation between democracy and innovation/growth is more positive and significant in more frontier economies.*

This prediction is confirmed by Aghion, Alesina and Trebbi (2007) using employment and productivity data at industry level across countries and over time.

This dichotomy between catch-up growth and innovation-led growth explains why countries like China grow faster than all OECD countries: growth in China is driven by technological imitation, and when one starts far below the frontier, catching up with the frontier means a big leap forward. Second, it explains why growth policy design should not be exactly the same in developed and in less developed economies. In particular, an imitative economy does not require labor and product market flexibility as much as a country where growth relies more on frontier innovation. Also, bank finance is well adapted to the needs of imitative firms, whereas equity financing (venture capital,...) are better suited to the needs of an innovative firm at

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[10] Aghion, Boustan, Hoxby and Vandenbussche (2009) show that research-type education is always more growth-enhancing in US states that are more frontier, whereas a bigger emphasis on two-year colleges is more growth-enhancing in US states that are farther below the productivity frontier. Similarly, using cross-country panel data, Vandenbussche, Aghion and Meghir (2006) show that tertiary education is more positively correlated with productivity growth in countries that are closer to the world technology frontier.

[11] Acemoglu and Robinson (2006) formalize another reason, also Schumpeterian, as to why democracy matters for innovation: namely, new innovations do not only destroy the economic rents of incumbent producers, they also threaten the power of incumbent political leaders.

the frontier. Similarly, good primary, secondary, and undergraduate education is well suited to the needs of a catching-up economy whereas graduate schools focusing on research education are more indispensable in a country where growth relies more on frontier innovations. This in turn suggests that beyond universal growth-enhancing policies such as good property right protection (and more generally the avoidance of expropriating institutions) and stabilizing macroeconomic policy (to reduce interest rates and inflation), the design of growth policy should be tailored to the stage of development of each individual country or region.

Innovation, institutions, and firm dynamics in developing countries   Firm dynamics show massive differences across countries. In a recent work, Hsieh and Klenow (2014) show that while establishments grow 5 times relative to their entry size by the age of 30, Indian counterparts barely show any growth. Why do establishments do not grow in India? Bloom et al. (2013) have empirically shown that *lack of trust* and the weak rule of law is a major obstacle to firm growth.

What are the aggregate implications of the lack of delegation and weakness of rule of law on productivity and firm dynamics? To answer this question, Akcigit, Alp, and Peters (2014) extend the firm dynamics model introduced in the previous section, by adding two major ingredients: (*i*) production requires managers and unless firm owners delegate some of the tasks, firms run into span of control problem as owners' time endowment is limited; (*ii*) firm owners can be of two types, high or low. High-type firms are more creative and have the potential of expanding much faster than low type firms. Whether this fast expansion is materialized or not depends on the return to expansion which itself depends on the possibility of delegation.

The predictions, both on the delegation margin and on the firm dynamics can be summarized as follows:

Prediction 1:   *Everything else equal, the probability of hiring an outside manager and, conditional on hiring, the number of outside managers is (i) increasing in firm size, (ii) decreasing in the owner's time, and (iii) increasing in the rule of law.*

Larger firms operate with more product lines and hence they have less time from the owner directly. Hence, the marginal contribution of an outside manager is much higher in larger firms. The second part relates the family size to delegation. If the owner has more time (due to larger family size, for instance), then the owner has already more time to invest in his business and this lowers the demand for outside managers. Finally stronger rule of law implies higher net return to delegation. AAP provide empirical support for these predictions using Indian manufacturing establishments.

Prediction 2:   *Average firm size: (i) increases in the owner's time, (ii) increases in the rule of law, and (iii) the positive relationship between firm size and the owner's time becomes weaker as the rule of law improves.*

Firm value is increasing in owner time and therefore the firms are willing to innovate and expand more when firm value is higher. The empirical support for the first part is provided by Bloom et al (2013). The positive link between firm size and the rule of law has been extensively documented in the literature (See for instance Bloom, Sadun, and Van Reenen (2012) for a detailed discussion). Finally, AAP show that the link between firm size and family size is weaker in high trust regions in India.

Prediction 3:   *Firm growth decreases in firm size, more so when the rule of law is weaker.*

This prediction follows from the fact that in larger firms, the owner has less time to allocate in each product line and hence the frictions to delegation become much more important for large firms. Hence, when the rule of law is weak, larger firms have less of an incentive to grow which means that the difference in growth incentives between large and small firms will be much more pronounced in weak rule of law countries or regions. AAP

show that growth decreases faster in firm size in low trust regions in India.

Prediction 4: *Everything else equal, creative destruction and reallocation among firms will be much higher in economies where the rule of law is stronger, thanks to the delegation possibilities.*

Clearly this latter prediction is in line with the main findings of Hsieh and Klenow's work which showed the missing growth and reallocation in developing countries. Understanding the reasons behind the lack of reallocation and creative destruction is essential in designing the right development policies. The Schumpeterian growth framework provides a useful framework to conduct counterfactual policy exercises which can shed light on this important debate.

3.1   Search frictions, innovation and growth

Peter A. Diamond, Dale T. Mortensen and Christopher A. Pissarides received their Nobel Prize in Economics for their research on "markets with search frictions." Their research was centered on the idea that in markets, buyers and sellers or workers and firms do not find each other immediately and it takes time for them to match. This delay was broadly attributed to so-called *search and matching (S&M) frictions* that exist in those markets that prevent the matches from happening immediately. But search market frictions in turn imply that creative destruction and therefore the growth process should affect the unemployment rate.[12]

And indeed Schumpeterian growth paradigm allows us to analyze the implications of frictional matching on the labor market for the relationship between innovation-led growth and unemployment. In particular it points to three counteracting effects of growth through creative destruction on the equilibrium unemployment level. While it is leading to incumbents getting replaced by new entrants and therefore release the workers of the incumbent firm to the unemployment pool: hence a positive *creative destruction effect* of innovation-led growth on unemployment (i.e a negative effect of innovation-led growth on the equilibrium employment rate). However, new firms entering the economy also create new jobs, hence a negative *job creation effect* of growth on unemployment (i.e a positive effect of innovation-led growth on the equilibrium employment rate). In addition to these two effects, more creative destruction implies higher growth and therefore a higher discounted value for new firms entering the market: hence a negative *capitalization effect* of growth on entry. Whether this capitalization effect increases or reduces equilibrium unemployment, depends upon which of the creative destruction and job creation effects dominates. If the creative destruction effect dominates, then the capitalization effect will reinforce the creative destruction effect. If the job creation effect dominates, then the capitalization effect will reinforce the job creation effect.

Now, when jobs can be destroyed for "exogenous" reasons, i.e. for reasons that do not have to do with innovation, then innovation becomes more a source of new job creation than mainly a source of job destruction. More precisely, the Schumpeterian theory of growth and unemployment with search frictions, predicts that:

Prediction 1: *When the rate of exogenous destruction is small the job destruction effect dominates the job creation effect and therefore growth and unemployment should be positively correlated.*

Prediction 2: *When the rate of exogenous job destruction is high, then the relationship is negative growth and unemployment: in that case the job creation effect of innovation-led growth on unemployment dominates the job destruction effect.*

This framework is used by Aghion, Akcigit, Deaton and Roulet (2015) to analyze the relationship between innovation-led growth and well-being. On the one hand more creative destruction implies more job destruction,

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[12]See Aghion and Howitt (1994) and Mortensen and Pissarides (1998).

which should reduce well-being of currently employed workers. On the other hand more creative destruction implies both, more new job creation and a higher growth rate, both of which should be welfare-enhancing. The authors generate and then test the following predictions using US data on subjective wellbeing and on job/firm turnover:

Prediction 3: *A higher turnover rate increases wellbeing more when controlling for aggregate unemployment, than when not controlling for aggregate unemployment.*

Prediction 4: *Higher turnover increases wellbeing more, the more turnover is associated with growth-enhancing activities.*

Prediction 5: *Higher turnover increases wellbeing more, the more generous unemployment benefits are.*

4 Enhancing productivity growth in advanced countries

4.1 Pillars of innovation-led growth

To enhance productivity growth in advanced countries, where growth relies more on frontier innovations, it helps to invest more in (autonomous) universities, to maximize flexibility of product and labour markets and to develop financial systems that rely importantly on equity financing.

Figure 1 below (from Aghion et al, 2009a) shows how competition (here measured by the lagged foreign entry rate) affects productivity growth in domestic incumbent firms. The upper curve averages among domestic firms that are closer to the technological frontier in their sector worldwide, compared to the median. We see that on average productivity growth in those firms responds positively to more intense competition. This reflects an "escape competition effect", i.e. the fact that such firms innovate more to escape the more intense competition. In contrast, productivity growth in firms that are farther below the technological frontier in their sector worldwide than the median, reacts negatively to more intense competition. This reflects a discouragement effect: firms far below the frontier know they have little chance to win against a potential entrant; thus the higher the entry rate, the more discouraged such firms are to invest in innovation and productivity growth. Now, the closer a country is to the world leading productivity level, the higher the fraction of firms close to the corresponding technological frontier, and therefore the more productivity-enhancing is product market competition.

FIGURE 1 HERE

Similarly, Aghion et al (2009c) show that more flexible labor markets (which facilitate the process of creative destruction) foster productivity growth more in more advanced countries. This is quite intuitive: the more advanced a country, the more productivity growth relies on frontier innovation. But frontier innovation in turn entails more creative destruction, and thus more job turnover, than technological catch-up.

A third lever of productivity growth in advanced countries is graduate education: indeed frontier innovation requires frontier researchers and therefore good universities and research centers, whereas good undergraduate education is sufficient for imitation. Figure 2, drawn from Aghion et al (2009b) shows that research education enhances productivity growth more in more frontier US states, i.e. in states with a higher per capita GDP (California, Massachusetts,..): these are states where a higher fraction of firms are "frontier-firms", i.e. firms with levels of productivity that are close to the best practice in the corresponding sector. On the other hand, two-year college education is what enhances productivity growth more in less advanced states

(Alabama, Mississippi,..): in those states, imitation (i.e. catch-up growth) is the main source of technological progress, and good undergraduate education enhances imitation. The same is true across countries: higher (and especially graduate) education enhances productivity growth more in countries with higher per capita GDP (see Vandenbussche et al (2006))..

FIGURE 2 HERE

A fourth lever of productivity growth is the organization of the financial sector. As shown by Figure 3 below (drawn from Koch, 2014), choosing a bank based financial system enhances productivity growth more for less advanced countries whereas choosing a more market-based financial system enhances productivity growth more in more frontier countries. The intuition is as follows: frontier-innovation which breaks new ground entails a higher level of risk than imitation activities which are already well defined. But this in turn implies that outside financiers involved in frontier-innovation will ask for a higher share of upside revenues and also for higher control rights: hence the role of equity in financing frontier innovation.

FIGURE 3 HERE

Aghion et al (2009c) have performed cross-country panel regressions of productivity growth on the share of ICT in total value added and found a positive significant coefficient (see Table 5 below, first three columns) on ICT. In other words, everything else equal, productivity growth appears to be positively correlated to ICT diffusion. But interestingly, once the authors control for product market regulation, the coefficient on ICT becomes non-significant. This in turn suggests that the positive ICT coefficient mentioned above reflects something more fundamental than ICT, namely, the effect of liberalizing product or labor markets and of investing in research education: these policies enhance productivity growth in developed economies, in part because they facilitate the diffusion of Information Technologies (ICT). We will come back to this point below when looking at the diffusion of technological waves across countries.

TABLE 1 HERE

Most recently, Cette, Lopez and Mairesse (2013) analyze the impact of anticompetitive regulations in upstream (service industry) sectors on productivity growth in downstream industries that are using inputs from those upstream sectors. Using an unbalanced country-industry panel dataset covering fifteen OECD countries over the period 1987-2007, the authors find that anticompetitive upstream regulations have a significantly detrimental effect on productivity growth downstream, and that this effect operates in part (but not entirely) through R&D and ICT investments in downstream industries.

4.2 Two fallacies on competition policy

4.2.1 Competition policy against patent policy

A thought-provoking book by Boldrin and Levine (2009) argues that patents are always detrimental to competition and thereby to innovation. To provide support to their analysis these two authors built a growth model where innovation and growth can occur under perfect competition. The model is then used to argue that monopoly rents and therefore patents are not needed for innovation and growth: on the contrary, patents are detrimental to innovation because they reduce competition.

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However, we have seen in the previous section that in the step-by-step Schumpeterian growth model, where a laggard firm needs to catch up with the current leader in its sector (and therefore go through a neck-and-neck stage) before it could later become a leader itself, not only can competition enhance innovation as in Boldrin and Levine's model, but also and perhaps more importantly competition and IPRs become complementary policies. Why? Because the incentive to innovate depends on the gap between the post-innovation rent and the pre-innovation rent, call it the net innovation rent. And typically, what competition does is to lower pre-innovation rents, and also maybe post-innovation rents, although the difference between post- and pre-innovation rents will increase with competition, and all the more so with stronger patents to protect post-innovation rents. [13]

In a recent paper published in ReStat, Yi Qian (2009) uses the passage of national pharmaceutical patent law as a natural experiment to test the economic impact of patent. She finds that implementation of patents stimulates innovation mostly in countries with higher market freedom. Similarly, Aghion, Howitt and Prantl (2015) look at the effects of implementation of the single market program on R&D expenditures in countries with different degrees of IPR. Thus we look at 13 manufacturing industries in 15 OECD countries between 1987 and 2005, and we find that the implementation of the single market program lead to an increasing R&D expenditure in countries with strong IPR, not in others. And the positive response of R&D expenditure to the single market program in strong IPR countries is more pronounced among firms in industries whose equivalent in the US indicate higher patent intensity. So there truly seems to be this complementarity between IPRs and competition.

4.2.2 Competition policy against industrial policy

Another fallacy, is that sectoral policies are always detrimental to competition and therefore they should always be precluded if we (justifiably) believe in the virtues of competition for innovation-led growth. Here, our answer is that sectoral policy can be designed and governed in a way that reconciles it with the need for more product market competition.

Indeed, the "pick winner" objection against sectoral policy loses bite when vertical targeting is properly designed and governed: in particular, when: (i) *the government chooses to pick activities, not particular firms*: indeed, while governments and policy makers do not have all the knowledge and wisdom needed for proper vertical selection, identifying activities with high growth potential is presumably easier than selecting individual firms[14]; (ii) *the criteria underlying the selection of activities are clear and verifiable:* in particular, recent research[15] points at skill-intensity and the degree of product market competition as relevant selection criteria for vertical targeting; (iii) *the vertical interventions are properly governed:* in particular, they should be governed in a way that preserves or even enhances product market competition in the corresponding sectors, and also in a way that guarantees exit from non-performing activities.

First empirical support for rethinking sectoral policy, is provided by Nunn and Trefler (2009). These authors use micro data on a set of countries, to analyze whether, as suggested by the argument of "infant industry", the

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[13] In contrast, in innovation-based growth models (Romer, 1990; Aghion and Howitt, 1992) where innovations are made by outsiders who then leap-frog incumbent firms, the pre-innovation rent is always equal to zero, thus all what competition does in this case is to reduce the post-innovation rent which is also equal to the net innovation rent.

[14] Activities that come to mind when talking about vertical targeting, most often pertain to the same four or five sectors, namely energy, biotech, ICT, transportation,..

[15] E.g. by Nunn and Trefler (2009), and Aghion et al (2015) which we summarize below.

growth of productivity in a country is positively affected by the measure in which tariff protection is biased in favor of activities and sectors that are "skill-intensive", that is to say, use more intensely skilled workers. They find a significant positive correlation between productivity growth and the "skill bias" due to tariff protection. Of course, such a correlation does not necessarily mean there is causality between skill-bias due to protection and productivity growth: the two variables may themselves be the result of a third factor, such as the quality of institutions in countries considered. However, Nunn and Trefler show that at least 25% of the correlation corresponds to a causal effect. Overall, their analysis suggests that adequately designed (here, skill-intensive) targeting may actually enhance growth, not only in the sector which is being subsidized, but also the country as a whole.

More recently, Aghion, Dewatripont, Du, Harrison and Legros (2015), henceforth Aghion et al (2015b), argue that sectoral policy should not be systematically opposed to competition policy. They use Chinese firm-level panel data. More precisely, they use firm-level panel data from the Chinese National Business Survey and regress productivity growth, patenting, or other measures of innovativeness and entrepreneurship, over various measures of sectoral intervention (subsidies, tariffs,...) interacted with the degree of competition in the sector, and also with the extent to which intervention in each sector is not concentrated on one single firm, but rather distributed over a larger number of firms. They show that TFP, TFP growth and product innovation (defined as the ratio between output value generated by new products to total output value) are all positively correlated with the interaction between state aid to the sector and market competition in the sector. Thus the more competitive the recipient sector, the more positive the effects of targeted state subsidies to that sector on TFP, TFP growth, and product innovation in that sector. Moreover, Aghion et al (2015b), show that the interaction between state aid and product market competition in the sector, is more positive when state aid is less concentrated.

And finally Acemoglu et al (2013) extend the Klette-Kortum model of growth and firm dynamics to allow for high versus low R&D productivity firms. Their model implies that subsidizing incumbents' R&D inhibits the entry of high-efficiency firms, which in turn can be detrimental to growth and welfare. We get back to this paper in more details in Section 5 below.

Yet this does not address the issue of why vertical targeting would be at all needed. A main theoretical argument in support of vertical targeting, is the existence of knowledge spillovers. Thus, Aghion et al (2015c) explore a cross-country panel data set of patents in the automotive industry. They distinguish between "dirty innovations" which affect combustion engines, and clean innovations such as those on electric cars. Then they show that the larger the stock of past "dirty" innovations by a given entrepreneur, the "dirtier" current innovations by the same entrepreneur. This "path dependence" phenomenon, together with the fact that innovations have been mostly dirty so far, implies that in the absence of government intervention our economies would generate too many dirty innovations. Hence a role for government intervention to "redirect technical change" towards clean innovations. Indeed Aghion et al (2015) show that an increase in carbon price (e.g. through carbon taxes) induces firms to redirect innovation towards clean technologies (e.g. to develop electric cars).

A reinforcing factor is the existence of credit constraints which may further limit or slow down the re-allocation of firms towards new (more growth-enhancing) activities. Now, one can argue that the existence of market failures on its own is not sufficient to justify vertical intervention. On the other hand, there are activities –typically high-tech activities- which generate knowledge spillovers on the rest of the economy, and where assets are highly intangible which in turn makes it more difficult for firms to borrow from private capital

markets to finance their growth.

4.3 Reforming the state

Aghion and Roulet (2011) use Schumpeterian growth theory to discuss why and how the welfare state should be reformed in the process of making the transition to an innovation-led economy. One extreme view is that the state should remain organized as it was when European countries were in a catching-up phase (from 1945 to the early 1970s). Another extreme view is that the transition from catch-up growth to innovation-led growth, should lead to a radical reform of the state, with the state withdrawing from the economy almost completely, except when it comes to law and order, national security and defense, and basic public services.

However we depart from these two extreme views on the following grounds. First, the transition to innovation-led growth, where frontier innovation is associated with creative destruction, i.e. with the constant replacement of old activities by new activities, implies that the state must give up the old industrial policies based on the support of few national champions. Instead, the state must favor and accompany the process of creative destruction, and in particular implement sectoral policies that are competition-friendly. On the other hand, the existence of knowledge externalities (reinforced by the existence of credit constraints) implies that the state cannot completely withdraw from the economy. Thus one has to look for a third way between these two extremes. This is what we refer to as the "strategic state" or the "smart state".

In particular a main issue facing countries in the euro area, particularly in its Southern part, is how to reconcile the need to invest in the main levers of innovation-led growth with that of reducing public debt and deficits. To address the challenge of reconciling growth with greater budgetary discipline, governments and states must become strategic. This first means to adopt a new approach to public spending: in particular, they must depart from the Keynesian policies aimed at fostering growth though indiscriminate public spending, and instead become selective as to where public funds should be invested. They must look for all possible areas where public spending can be reduced without damaging effects on growth and social cohesion: a good example are the potential savings on administrative costs: technical progress in information and communication makes it possible to decentralize and thereby reduce the number of government layers, for similar reasons as those that allowed large firms to reduce the number of hierarchical layers over the past decades. Decentralization makes it also easier to operate a high quality health system at lower cost, as shown by the Swedish example.

Second, governments must focus public investments on a limited number of growth-enhancing areas and sectors: education, universities, innovative SMEs, labor market policies and support to labor and product market flexibility; industrial sectors with high growth potential and externalities as we argued above.

Third, governments must link public financing to changes in the governance of sectors they invest in: how can one make sure that government funds will be appropriately used? For example, public investments in education must be conditional upon schools taking concrete steps to improve pedagogical methods and to provide individual support to students. Similarly, the necessary increases in higher education investments must be conditional upon universities going for excellence and adopting the required governance rules. For example Aghion et. al. (2010) show that investments in higher education are more effective the more autonomous universities are and the more competitive the overall university system is (in particular, the more funding relies on competitive grants).

4.4 Macroeconomic policy

Recent studies (see Aghion, Hemous, and Kharroubi, 2009; Aghion, Farhi and Kharroubi, 2012) performed at cross-country/cross-industry level, show that more countercyclical fiscal and monetary policies enhance growth. Fiscal policy countercyclicality refers to countries increasing their public deficits and debt in recessions but reducing them in upturns. Monetary policy countercyclicality refers to central banks letting real short term interest rates go down in recessions while having them increase again during upturns. Such policies can help credit-constrained or liquidity-constrained firms to pursue innovative investments (R&D, skills and training,...) over the cycle in spite of credit tightening during recessions, and it also helps maintain aggregate consumption and therefore firms' market size over the cycle (see Aghion and Howitt, 2009, ch. 13). Both contribute to encouraging firms to invest more in R&D and innovation. This view of the role and design of macroeconomic policy departs both, from the Keynesian approach of advocating untargeted public spending to foster demand in recessions, and from the neo-liberal policy of just minimizing tax and public spending in recessions.

Note that such policies are complementary to the above mentioned structural policies aimed at favoring innovation-led growth, namely product market liberalization, labor market flexibility and training, and higher education reform. As well argued by Mario Draghi in his Bretton Woods speech a year ago, quantity easing and other devices to increase the flexibility of macroeconomic policy in the Euro area, will have little effect on productivity growth if they are not accompanied by systematic structural reforms that make it easier for new firms to enter the product market and hire on the labor market.

4.5 Innovation, inequality, and social mobility: making growth inclusive

Figures 4 and 5 below show innovation (measured by the flow of patents per 1000 inhabitants) and top income inequality (measured by the share of income accruing to the top 1% income earners) over the past fifty years, respectively for the US and for Sweden. In both cases, we see that innovation and top income inequality follow parallel evolutions, first essentially flat until the late seventies and then sharply increasing since the early 1980s.

FIGURES 4 AND 5 HERE

Does that mean that innovation necessarily leads to increased inequality? And what can governments do to reconcile innovation-led growth with the need to avoid excessive inequality and instead maintain social cohesion?

In recent work, Aghion et al (2015d) use cross-US-state panel data on patenting and inequality over the period 1975-2010 to show that: (i) the top 1% income share in the US state is positively and significantly correlated with the state's degree of innovativeness, i.e. with the quality-adjusted amount of innovation in this country or state, which they measure by citation count; (ii) the effect of innovation on top income inequality is (at least partly) causal, from innovation to top income inequality[16] (iii) in cross-state panel regressions, innovativeness is less positively or even negatively correlated with measures of inequality which do not emphasize the very top incomes, in particular the top 2 to 10% income shares (i.e. excluding the top 1%), or broader measures of inequality like the Gini coefficient. From cross-section regressions performed at the CZ level, Aghion et al (2015d) also find that: (i) innovativeness is positively correlated with upward social

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[16] They establish this result by instrumenting for innovativeness following two different strategies, first by using data on the appropriation committees of the Senate, and second by relying on knowledge spillovers from the other states.

mobility; (ii) the positive correlation between innovativeness and social mobility, is driven mainly by entrant innovators and less so by incumbent innovators, and it is dampened in states with higher lobbying intensity.

In short, innovation tends to increase top income inequality, but not inequality at large[17] And moreover innovation appears to be positively correlated with social mobility. However, both, entrant innovation and social mobility are dampened by lobbying activities.

What are the implications of these findings for policy design aimed at making growth more inclusive? Investing more and better in schools and universities, clearly has the effect of increasing growth while also fostering social mobility. But what is more interesting in the sense that it goes against the popular view, is that structural reforms such as product and labor market liberalization, which enhance productivity growth as we have argued above, also increase social mobility to the extent that they favor innovation and creative destruction.[18] Thus the three pillars of an innovation-led growth strategy, namely (higher) education, product market flexibility, and labor market flexibility, lie at the heart of an inclusive growth strategy.

Now, what about taxation policy? There is a whole theoretical literature on how capital and labor income should be optimally taxed. However, somewhat surprisingly, very little has been done on taxation and growth, and almost nothing in the context of an economy where growth is driven by innovation. Absent growth considerations, the traditional argument against taxing capital is that this discourages savings and capital accumulation, and amounts to taxing individuals twice: once when they receive their labor income, and a second time when they collect revenues from saving their net labor income. Introducing endogenous growth may either reinforce this result (when the flow of innovation is mainly driven by the capital stock) or dampen it (when innovation is mainly driven by market size which itself revolves around employees' net labor income). A An analysis of optimal taxation policy in the context of an innovation-led economy, is beyond the scope of this paper and represents a huge new research agenda. Yet, one can learn from the tax reforms implemented in some developed countries during the past decades. In particular, it is widely acknowledge that by deciding to: (i) lower its maximal tax rate on labor income from around 90% before 1991 to 57% after 1991; (ii) move from a progressive tax schedule on capital income with a maximum marginal tax rate at 72% before 1991 to a flat rate of 30% after 1991, Sweden has spurred innovation-led growth (as shown by the acceleration in patenting and in productivity growth after 1991), while still maintaining public services (health, schools and universities) of high quality and available to all for free. Moreover, Sweden remains the second least unequal country worldwide.

5 Technological waves and the debate on secular stagnation

5.1 The debate

Based on the (apparent) slowing down of productivity growth in advanced countries since 2001, Gordon (2012, 2013) holds that the IT revolution is over and moreover that the slowdown is there to last for a long period to come. His view is that: (i) the IT wave exhausted its growth-enhancing power; (ii) several factors make the arrival of a new wave unlikely in the near future: in particular, the demographic transition, the limits in the growth of educational attainment, the rising income and wealth inequality resulting in mounting household

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[17]In Sweden for example, the Gini has not increased over the past twenty five years, whereas both, patenting and top income inequality have.

[18]See Aghion and Roulet (2014).

debts that add to government debts. We disagree with that pessimist view for at least three reasons. First, as pointed out by Dale Jorgenson and others, the IT revolution has durably changed the technology for producing ideas: in particular, it has made it easier for researchers to communicate and interact at long distance, which has certainly contributed to increasing the flow of new ideas. And we already see new ideas about to be implemented, which could revive the IT wave, such as the 3D chips and 3D printing. Second, there is an obvious demand for new fundamental innovations, for example in renewable energies and in bio techs, both by individuals and by governments. Third, as stressed by Byrne et al (2013), the apparent slow down in the contribution of IT to productivity growth, can be due to measurement problems: in particular Byrne et al. make the argument that the BLS price index has not properly factored in the continuous progress in semi-conductor technology: the rate of decline in the price of semi-conductor embodying products has been underestimated according to these authors.

But there another consideration, made by Bergeaud, Cette and Lecat (2014), which directly links to the focus of this survey: the IT wave is diffusing with delays to countries other than the US, and the delay is most important in countries which have not yet fully implemented the structural reforms (university reform, product and labor market liberalization) required for a successful transition to innovation-based growth.

5.2 Historical wave patterns

In the remaining part of this section we take a brief look at technological waves and their diffusion from US to other developed countries. In particular we will point at the relationship between structural reforms and a country's ability to take advantage of the new IT wave. We define a technological wave as the diffusion of new General Purpose Technologies (GPT)[19]. General Purpose Technologies (GPTs) are defined as generic technologies which affect most sectors of the economy. Obvious examples include steam energy in the early and mid 19th century, electricity and chemistry in the early 20th century, and the Information and Communication Technology revolution in the 1980s. While innovation-led productivity growth goes beyond the diffusion of these generic technologies, the speed at which a country adopts and diffuses a new General Purpose Technology, reflects the country's ability to innovate more generally. It is therefore of interest to compare the diffusion patterns of General Purpose Technologies across countries, especially when showing that lags in such diffusion reflect market or institutional rigidities which hamper innovation-led growth more generally.

5.2.1 Two productivity growth waves

Using annual and quarterly data over the period 1890-2012 on labor productivity and TFP for 13 advanced countries (the G7 plus Spain, The Netherlands, Finland, Australia, Sweden and Norway) plus the reconstituted Euro area, Bergeaud, Cette and Lecat (2014) (BCL thereafter) show the existence of two big productivity growth waves during this period.

The first wave culminates in 1941, the second culminates in 2001. The first wave corresponds to the second industrial revolution: that of electricity, internal combustion and chemistry (Gordon, 2000). The second wave is the ICT wave. That wave of smaller magnitude than the first, and a big question is as to whether that second wave has ended in the US.

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[19]See Bresnahan and Trajtenberg (xxxx).

5.2.2 Diffusion patterns

Figure 6 from Cette and Lopez (2012) shows that the Euro Area[20] and Japan suffer from a lag in the diffusion of technological waves compare to the US. Thus the first wave fully diffused to the current euro area, Japan and the UK only post World War II. As for the second productivity wave, so far it does not show up in the Euro Area or in Japan. Market rigidities contribute to explaining such delays.

FIGURE 6 HERE

And through an econometric analysis, Cette and Lopez show that this lag of ICT diffusion in Europe and Japan, compare to the US, is explained by institutional aspects: a lower education level, on average, of the working-age population and more regulations on labour and product markets. This result means that by implementing structural reforms, these countries could benefit from a productivity acceleration linked to a catch-up of the US ICT diffusion level. The lower quality of research and higher education in the Euro area and Japan compared to the US also appears to matter for explaining the diffusion lag. These findings mirror those in Table 1.

5.2.3 Country-specific shocks and the role of reforms

Figure 7 from BCL (2014) shows a positive break in labour productivity and in TFP growth in Sweden after 1990. This stands in contrast with the case of Japan shown on Figure 8: there, we see no such break but instead decelerating labour productivity and TFP growth since 1980. Our explanation is that Sweden implemented sweeping structural reforms in the early 1990s: in particular a reform of the public spending system to reduce public deficits, and a tax reform to encourage labour supply and entrepreneurship. No significant reform took place in Japan over the past thirty years.

Consider from BCL (2014) study the four countries which are commonly presented as lead reformers over the past three decades. The reforms initiated in Sweden in the early 1990s made the rate of TFP growth increase from an average of 0.4% over the period 1976-1992 to an average of 1.9% over the period 1992-2008. Similarly, the 1982 reform (Wassenaard agreement) in the Netherlands is associated with a break from an average TFP growth rate of 0.5% over the period 1977-1983 to an average TFP growth rate of 1.5% over the period 1983-2002. The reforms initiated in the early 1990s in Canada are associated with a break from an average TFP growth rate of 0.3% over the period 1974-1990 to an average rate of 1.1% over the period 1990-2000. Finally, the reforms initiated in the early 1990s in Australia are associated with a break from an average TFP growth rate over the period 1971-1990 of 0.4% to an average growth rate of 1.4% over the period 1990-2002.

These findings are in line with cross-country panel regressions suggesting that structural reforms play a key role in speeding up the diffusion of technological waves.

FIGURES 7 AND 8 HERE

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[20] The Euro Area is here the aggregation of Germany, France, Italy, Spain, The Netherlands, Austria and Finland. These seven countries represent together, in 2012, $88\frac{1}{2}$% or the total GDP of the Euro Area.

6 Schumpeterian insights into R&D policy

How should the optimal R&D policy be designed? This question is at the heart of any policy debate which targets technological progress through R&D and innovation. Many governments are providing massive subsidies to foster innovation. As an example, the United States spends more than \$130 billion per year at the federal level to support innovation (NSF + NIH + Army Research Office + R&D tax credit).[21] The proponents of R&D subsidy have argued that R&D has spillovers that are not internalized by the innovating firms. The opponents claim that product market competition already provides sufficient incentives to firms and that any additional subsidy would be wasteful.

In this section, summarizing the findings from recent research on R&D policy from the Schumpeterian growth viewpoint, we argue that there are at least two new and important aspects that the design of optimal R&D policy should consider: namely, firm selection and the distinction between basic and applied research. The former implies that R&D policy could affect firm survival and consequently resource reallocation between more productive and less productive firms, or between incumbent and entrant firms. The latter relates to the fact that different types of research, in this case basic and applied, could have different spillovers and R&D policy should take into account its impact on the distinct types of research.

6.1 R&D policies and firm selection

The goal of R&D policies is to incentivize firms to undertake greater R&D investment, produce more innovations, increase productivity, and create more jobs. However, these policies do not affect every firm in the economy in the same way. For instance, Criscuolo et al. (2012) have shown that large incumbents are better at obtaining government subsidies. Therefore one can argue that R&D subsidies to incumbents might be inefficiently preventing the entry of new firms and therefore slowing down the replacement of inefficient incumbents by more productive new entrants. The turnover and factor reallocation between incumbents and entrants is an important source of productivity growth. Foster, Haltiwanger and Krizan (2000 and 2006) have shown empirically that the reallocation of factors across firms accounts for more than 50% of productivity growth in the US. Given the empirical importance of this reallocation margin, it is necessary that R&D policy takes into account the interaction between innovation and factor reallocation. This is our focus in Acemoglu et al. (2013).

Recent literature has emphasized the importance of firm size and age for firm level heterogeneity that are observed in the data (Akcigit and Kerr, 2015; Haltiwanger et al 2013). In particular Acemoglu et al (2013) uses data from the Census Bureau's Longitudinal Business Database and Census of Manufacturers, the National Science Foundation's Survey of Industrial Research and Development, and the NBER Patent Database. Their analysis focuses on innovative firms that are in operation during the 1987-1997 period. If we define small and large firms by their size relative to the median employment in the sample by year; and we define young and old firms by whether or not the firm is older than ten years, then the evidence points to small and young firms are both more R&D intensive and grow faster.[22] It then follows that industrial policies that discourage the reallocation of resources towards younger firms might indeed be costly in that they slow the movement of R&D resources from less efficient innovators (struggling incumbents) towards more efficient innovators (new

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[21] http://www.whitehouse.gov/sites/default/files/microsites/ostp/Fy%202015%20R&D.pdf

[22] Likewise Akcigit and Kerr (2015) regress firm growth on log firm size and find an estimate -0.04 and innovation intensity (number of innovations relative to the firm size) on log firm size and find an estimate of -0.18.

firms).

Acemoglu et al (2013) extend the Klette-Kortum model of growth and firm dynamics considered above by allowing for high versus low ability firms, i.e. firms with more versus less efficient R&D technologies. Then they calibrate their model by matching empirical moments capturing key features of firm-level R&D behavior, shipments growth, employment growth and exit, and the variation of these moments with size and age. Finally, they use the estimated model as a lab to run counterfactual experiments and test the impacts of various R&D policy designs on economic growth and welfare. The policies that we consider include a subsidy to new entrants, a subsidy to R&D by incumbents, and a subsidy for the continued operation of incumbents.

Their main findings can be summarized as follows. First, subsidizing incumbents reduces the equilibrium growth rate and welfare decrease. The reason is that this may prevent low-ability incumbents from exiting, thereby inhibiting the entry of high-ability firms. Solving for the optimal policy, the authors find that it involves a substantial tax on the operation of incumbents, combined with an R&D subsidy to incumbents. The reason for this result is that taxing operations makes it harder for low-type firms to survive and forces them to exit. This way the freed-up factors of production are reallocated to high-type firms, which make use of them much more effectively.

Overall, this general equilibrium analysis, which incorporates both reallocation and selection effects, highlights the fact that the economy in equilibrium might contain too many low-type firms and policies that ignore the selection effect might help low-type firms survive. Another point that is highlighted is the fact that intertemporal spillovers are sizable and the overall R&D investment is too little. Therefore a combination of R&D subsidies and taxes on firm operations could be an effective way of providing innovation incentives to firms, while also leveraging the selection margin in the economy.

6.2   Basic versus applied R&D

In many countries national funds allocated to basic research have been among the top items in governments' policy agendas. For instance, in a recent report by the US Congress Joint Economic Committee, it is argued that despite its value to society as a whole, basic research is underfunded by private firms precisely because it is performed with no specific commercial applications in mind. The level of federal funding for basic research is deemed "worrisome" and it is claimed that it must be increased in order to overcome the underinvestment in basic research (JEC, 2010) . However the report also complains about the lack of research studies that actually quantify the extent of this underinvestment and about the lack of data.[23]

For similar reasons governments introduce programs to promote collaboration between basic academic researchers and private firms, with the hope that synergies generated from these interactions could lead to breakthrough technological advances. For instance, the United States government has aggressively promoted collaboration between universities and industrial researchers through specific funding programs. Among many others, the National Science Foundation (NSF) sponsors the Fundamental Research Program for Industry-University Cooperative Research (FRP), the Industry-University Cooperative Research Centers Program (I/UCRC) and Grant Opportunities for Academic Liaison with Industry (GOALI).

Although the different characteristics of basic and applied research on the one hand and academic and corporate research on the other hand have been widely recognized to be of first-order importance by policy makers, these issues have received insufficient attention in the economic literature on productivity and economic

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[23]http://jec.senate.gov/public/?a=Files.Serve&File_id=29aac456-fce3-4d69-956f-4add06f111c1

growth. In particular, the endogenous growth literature has mainly considered a uniform type of (applied) research and overlooked basic research investment by private firms.

What are the key roles of basic and applied research for productivity growth? How should R&D policy be geared towards basic versus applied research? What are the incentives of private firms to conduct basic research? How does academic research contribute to innovation and productivity growth? Akcigit, Hanley and Serrano-Velarde (2014) provide a first attempt at answering these questions. In order to understand the potential inefficiencies involved in different types of research investments and to design appropriate industrial policies to address them, it is necessary to adopt a structural framework that explicitly models the incentives for different types of research investments by private firms. Akcigit et al (2014) take an important step toward developing this theoretical framework, identifying the potential spillovers, and studying their macroeconomic implications for innovation policy.

Their analysis starts from the observation that countries allocate a significant share of their GDP to R&D (around 2-3%). The question then is: which fraction of it goes to basic versus applied research? The interesting fact is that almost half of overall spending goes into basic research.[24]

Akcigit et al (2014) first test Nelson (1959)' s view that "firms which support research toward the basic-science end of the spectrum are firms that have *fingers in many pies*". According to this argument, as the range of its products and industries gets more diversified, a firm's incentive for investing into basic research relative to applied research should increase due to better appropriability of potential knowledge spillovers. To measure multi-industry presence, the authors count how many distinct SIC codes a firm is present in. Using micro-level data on French firms, they plot average basic research intensity against the total number of distinct 1 digit SIC codes in which the firm is present. And they find a positive and statistically and economically significant relationship between multi-industry presence and basic research spending. A broader technological base is associated with higher investment in basic research relative to applied research. Thus the authors support Nelsons' hypothesis about the link between multi-industry presence and relative research incentives. These correlations are robust to a large variety of potential confounding factors. This result suggests that cross-industry spillovers are sizable and using the variation in firms' technology base, we can estimate the cross-industry spillovers associated with basic research.

In order to study the policy implications of these spillovers, Akcigit et al (2014) build a general equilibrium, multi-industry framework with private firms and a public research sector. Firms conduct both basic and applied research, whereas the public sector focuses exclusively on basic research. In their model, basic research generates fundamental technological innovations and generates spillovers, both within and across industries, that affect subsequent applied innovations.[25] In line with the "Ivory Tower" theory of academic research, basic research by private firms in this model will turn into consumer products faster than that undertaken by public research labs. Applied research, on the other hand, will be done only by private firms and will generate follow-on innovations building on the existing basic knowledge stock.

The authors then undertake a quantitative investigation of the impacts of various innovation policies on the aggregate economy. They first estimate the model by targeting some of the key moments in the data, especially public and private spending on basic and applied research in France. Then they use the estimated

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[24]See Akcigit et al (2014) for references.

[25]By fundamental innovation, we mean major technological improvements that generate larger than average contributions to the aggregate knowledge stock of society. In addition, these will have long-lasting spillover effects on the size of subsequent innovations within the same field.

model to assess the extent of inefficiencies in basic and applied research and to study the implications of several important innovation policies.

Their main results can be summarized as follows. First, a large fraction of spillovers from basic research across industries are not internalized. As a result, there is a dynamic misallocation of research efforts, which reduces welfare significantly. One striking result is that the decentralized economy and the social planner's economy are using overall the same level of resources for research. However, the composition of the total research effort is very distinct. While the social planner is allocating more resources to basic research, it allocates less resources to applied research. This implies that the dominant misallocation here is not that between production and research, but among the various types of research activities, in this case, applied and basic research. There is actually *overinvestment* in applied research in the decentralized economy because of product market competition, whereas there is underinvestment in basic research due to uninternalized within-industry and cross-industry spillovers.

This raises an important question: to what extent can public policies address this inefficiency? The first policy we analyze is a uniform research subsidy to private firms. In this environment, subsidizing overall private research is ineffective since this will oversubsidize applied research, which is already excessive due to product market competition. Therefore, the welfare improvement from such a subsidy is limited, unless the policymaker is able to discriminate between types of research projects at the firm level, a difficult task in the real world.

The authors then analyze another policy tool: the level of funding for public research labs. We show that due to the Ivory Tower nature of public basic research, allocating more money to the academic sector without giving property rights to the researchers (ownership over their inventions) is not necessarily a good idea. To demonstrate this, they simulate a policy similar to the Bayh-Dole Act enacted in the US in 1980. They consider alternative scenarios in which public researchers have no property rights, then 50% and 100% property rights. And they find a complementarity between the level of property rights and the optimal allocation of resources to academic research. The optimal combination turns out to grant full property rights to the academic researcher and allocating a larger fraction of GDP to public research. This reduces the welfare gap significantly.

7   The role of freedom and openness in the innovation process

How do incentives and organizations affect the probability and nature of innovation? As well explained by Pierre Azoulay in his lecture notes, providing incentives for producing ideas is problematic for at least three reasons. First, ex ante it is difficult to describe the innovation in advance. Second, ex post property rights on innovations may be difficult to enforce (for example, how do we enforce patent breadth). Third, innovation efforts are hard to observe and verify.

In short, a contract for future innovation is bound to be an incomplete contract, one whereby the contracting parties allocate property rights on the realized innovation and/or decision rights on the innovation process, leaving much of the revenue sharing to expost bargaining[26].

In this section we explore one particular implication of contractual incompleteness, namely the issue of how to allocate control rights on the choice of research agenda in the context of multi-stage research lines.

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[26]Of course, the monetary incentives for innovation are not only determined by ex post bargaining: ex post monetary rewards through prizes, as well as ex ante financing of R&D as part of research grants or procurement contracts, also play an important role in inducing innovation.

This leads us to revisit the role of intellectual property (IP) versus academic freedom and openness in the innovation process.

7.1 The ADS framework and the role of academic freedom

The incentives of academics are known to be different from those of private researchers (see Dasgupta and David, 1990). Building on an emerging body of research in the new economics of science (Dasgupta and David, 1994; Stern, 2004), Aghion, Dewatripont and Stein (2008, henceforth ADS) emphasize the role of intellectual freedom: granting control rights to allow researchers to select their own research agenda.

More formally, ADS consider a multi-stage research line. The line starts with an initial idea I_0. Then the idea is elaborated upon in stages. If stage 1 is successful, there is a refined idea I_1; this refined idea can be pursued further to potentially generate an even-more-refined idea I_2, etc. There are a total of k stages after the initial idea. If and only if all k stages are successful, there is a final idea I_k which generates a terminal value V, e.g. in the form of a marketable product.

Each stage on the research line requires one researcher, and that researcher succeeds with probability p if she follows a (success-maximizing) practical strategy at that stage. Instead of the practical strategy, the researcher may choose to follow an "alternative" strategy which yields a zero probability of success. One interpretation is that the alternative strategy may be the one that the researcher enjoys more, even though it does not pay off in monetary terms. Another interpretation is that the alternative strategy may help initiate new lines but does not generate progress on the initial line.

There is an infinite supply of researchers at each stage, each of whom has an outside option R that she can obtain by working in another profession. After being exposed to idea I_{j-1}, each researcher at stage j decides whether she would better enjoy following the practical strategy or the alternative strategy. If she is able to undertake her favored strategy, she suffers no disutility from working. However, if the researcher has to undertake the strategy that she likes less, she suffers a disutility of z. The ex ante probability that a given researcher prefers to follow the practical strategy is given by α. ADS assume that the choice of the practical vs. the alternative strategy is ex ante non-contractible. In other words, one cannot write a contract that promises a bonus for following the practical strategy, because the nature of work that strategy entails cannot be adequately described ahead of time.

If the researcher is employed by a university which leaves her with full control rights over the choice of research strategy (the "researcher-freedom" regime), in equilibrium, she is paid the reservation wage $w^{freedom} = R$, and always works on her preferred strategy. This implies that with probability α, the scientist works on the practical strategy, and with probability $(1 - \alpha)$, she works on the alternative strategy. Therefore, the ex-ante probability of advancing to the next stage is given by αp.

Suppose instead that the researcher is employed by a centralized firm who has full control rights on the choice of research agenda. Then, ex-post, the manager has the authority to force the researcher to work on the practical strategy. Anticipating this, the researcher will demand a wage of $w^{firm} = R + (1 - \alpha)z$ in order to work under this "manager-control" regime. The $(1-\alpha)z$ markup over the researcher-freedom regime represents compensation for loss of creative freedom–the fact that the researcher now must always adopt the practical strategy, whether this turns out to coincide with her preferences or not.

ADS show that it is optimal to allocate control rights on the research agenda (i.e. to grant academic freedom) in early stages of the research line, as this reduces the cost of research (the researcher asks for

$w^{freedom} = R$ instead of $w^{firm} = R + (1 - \alpha)z$), whereas for later stages in the research line focus on the practical strategy becomes paramount, so that it is optimal to have research performed within a firm.

More generally, whether the researcher will or will not enjoy control rights -i.e. real authority- over her research agenda, will depend upon how strongly she is monitored by the firm that employs her.

For example, consider a two-stage research process. In each stage $i = 1, 2$ the firm owner hires a scientist, and agrees to pay her a wage of w_{pi}. Next, the firm owner invests effort in trying to become informed about the project. For an effort cost of $\theta\lambda^2/2$, the firm owner has a probability λ of becoming informed. If she is informed, she is then able to force the scientist to follow the practical strategy. However, if she is uninformed, the entrepreneur is unable to direct the scientist, and the scientist is thus free to do what she wants.

It is easy to show that: (i) the more the researcher is being monitored by the firm, the higher the wage the researcher will ask to compensate for her loss of control rights; (ii) it is optimal to grant more freedom to the researcher in the earlier stage (here, in stage $i = 1$) of the research process.

To prove these two claims, note that the payoff to the firm owner if she is informed at stage i is:

$$E(\pi_i^p \mid \text{informed}) = p\Pi_{i+1} - w_{pi},$$

whereas the payoff to the firm owner if she is uninformed at stage i is:

$$E(\pi_i^p \mid \text{uninformed}) = \alpha p\Pi_{i+1} - w_{pi},$$

so that the marginal value of being informed at stage i is $(1 - \alpha)p\Pi_{i+1}$, and the firm owner's equilibrium probability of becoming informed at this stage is:

$$\lambda_i = (1 - \alpha)p\Pi_{i+1}/\theta. \tag{2}$$

It follows that the unconditional expected payoff at stage i is given by:

$$\Pi_i = E(\pi_i^p) = (\lambda_i + \alpha(1 - \lambda_i))p\Pi_{i+1} - w_{pi} - \theta\lambda_i^2/2,$$

where the wage w_{pi} is itself determined as:

$$w_{pi} = R + \lambda_i(1 - \alpha)z. \tag{3}$$

Proving (i) and (ii) is now straightforward: first, from (2), as the project is getting closer to completion, the likelihood that the firm owner becomes informed and therefore imposes her choice of research strategy to the scientist increases, since Π_{i+1} goes up with i; second, from (3) we immediately get that the scientist's wage also increases, to compensate for the fact that he has less de facto creative control. In other words, research firms endogenously become more hands on in later stages of research projects.

7.2 Freedom and openness

Another implication of the ADS framework, is that openness should play an important role in early stage research, whereas later stages in the research process are bound to be more "proprietary". Indeed, when granted academic freedom, researchers are free to explore alternative strategies which may lead to the creation of new research lines that those researchers may not pursue. Then there is value in having other researchers freely access the knowledge that will enable them to pursue these new research lines. Openness is less justified in later stages of the research process when research is more focused and also closer to commercialization.

More formally, consider two parallel research lines, 1 and 2, each of which operates as described above. Namely, with ex ante probability α the researcher initially allocated to the current stage of either of these two lines, prefers to pursue the practical strategy for that line whereas with probability $(1-\alpha)$ he prefers not to pursue this practical strategy. Now openness implies that the scientist on line 1 can learn about project 2 and vice-versa, and that consequently with positive probability φ, she may choose to work on the practical strategy for project 2 if nobody else does. A greater degree of openness implies a higher value of φ.

What openness does, is to increase the net present value of a research line operated under freedom from

$$E(\pi_i^p \mid \text{uninformed}) = \alpha p \Pi_{i+1} - w_{pi}$$

to

$$E(\pi_i^p \mid \text{uninformed}) = [\alpha + (1-\alpha)\varphi]p\Pi_{i+1} - w_{pi}.$$

However, openness has no value when the firm owner controls the researcher's agenda, since the researcher is always forced to work on the practical strategy in that case. Thus we still have:

$$E(\pi_i^p \mid \text{informed}) = p\Pi_{i+1} - w_{pi}.$$

Hence:

$$\Pi_i = E(\pi_i^p) = (\lambda_i + (1-\lambda_i)[\alpha + (1-\alpha)\varphi])p\Pi_{i+1} - w_{pi} - \theta\lambda_i^2/2,$$

which in turn will lead to a lower equilibrium value of λ_i (particularly for lower i's) and therefore to more freedom (particularly at earlier stages on the research line) and thus to more new lines being created. As a result, a higher fraction of researchers will be working on early stages of research lines, hence there will be more basic research.

7.3   Evidence on the limits of IP and the role of openness and freedom

The above model generates the following predictions:

Prediction 1: Earlier stages of research should be managed in a more decentralized way, leaving more freedom to researchers.

There is some empirical research speaking to this prediction, although indirectly. For example, using French and British firm-level data, Acemoglu et al. (2007, AALVR) show that firms that encounter newer problems to solve tend to be more decentralized. This includes firms in more heterogeneous industries (where it is harder to learn from others), firms closer to the technological frontier (so that there are fewer other firms to learn from) and younger firms (thus with less experience to learn from their own mistakes). That more frontier firms should delegate more may also explain why subsidizing higher education, in particular graduate education, is more likely to be innovation-enhancing if universities are more decentralized (as shown for example by Aghion et al., 2010, using cross-US-state panel data). Incidentally, universities are a sector in which formal delegation can be more easily enforced.

Prediction 2: More openness: *(i) enhances research freedom; (ii) enhances the creation of new lines; (iii) enhances basic research* .

Murray et al (2008) test the prediction that in a research setting characterized by a high level of intellectual freedom, greater openness does not just increase the flow of research, but also increases the diversity of

new research discoveries. More precisely, they consider the following natural experiment in openness: NIH agreements in the late 1990s that reduced the costs of accessing information on genetically engineered mice. [27]Using a sample of engineered mice linked to specific scientific papers, some of which were affected by the NIH agreements and some were not, Murray et al (2008) evaluate how the level and nature of follow-on research changes after the NIH-induced increase in openness. They find that increased openness encourages entry by new researchers and the exploration of more diverse research lines.

Particularly influential has been Heidi Williams' contribution to the field. In particular Williams (2013) uses a fascinating dataset on the sequencing of the human genome to analyze the impact of the IP restrictions imposed by the private firm Celera until 2003, on subsequent innovation. The author finds that these restrictions have indeed negatively affected subsequent scientific research and product innovation.

Both, Murray et al (2008) and Williams (2013) have in common that they both analyze the impact of non-patent IP restrictions on subsequent innovation. More recently, Sampat and Williams (2015) have looked at the potential impact of gene patents on subsequent innovation on human genes. Somewhat surprisingly, using USPTO data on human genes the authors find that gene patents have no systematic effect on subsequent innovation.

8 Towards a new Growth Pact in Europe

The above discussion suggests some directions for a new growth package for EU and in particular countries in the Euro area: (i) structural reforms starting with the liberalization of product and labor markets: here we will argue that an important role can be played by structural funds provided the targeting and governance of these funds is suitably modified; (ii) industrial investments along the lines suggested by our above discussion on vertical targeting; (iii) more flexible macroeconomic policies (budgetary and monetary) at EU level.

8.1 Structural reforms and the role of structural funds

There is a broad consensus among European leaders regarding the importance of structural reforms, in particular product and labor market liberalization and higher education reform, to foster long run growth Europe. In this section we first assess the potential increase in growth potential from having all Eurozone countries converge fully or partly to the best standards with regard to product or labor market liberalization, and also with regard to higher education. In the second part of the section we discuss the role that structural funds might play in encouraging such reforms.

8.1.1 Assessing the growth effects of structural reforms

As in Aghion et al (2009c) one can look at the effect of structural policies using cross-country panel regressions across 21 European countries. Our structural indicators are the following: For higher education system : the share of the 25-64 years old population having completed tertiary education (SUP); for product market : an OECD index assessing product market regulation (PMR); for labor market : an OECD index assessing the strictness of employment protection (LPE). In fact we focus on the interaction between these two rigidities,

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[27]Specifically, in 1998 and 1999, the National Institutes of Health negotiated two Memoranda of Understanding with the firm DuPont, which granted academic researchers low-cost, royalty-free and independent access to both the use of DuPont's methods and to the transgenic mice associated with them through the Jackson Laboratory, a non-profit research mice repository.

namely the variable PMR*LPE, in the analysis of labor and product market reforms. Indeed, there are good reasons to believe the effects of liberalizing product markets are complementary to those of liberalizing labor markets: for example, making entry in a new activity easier is of lesser value to an entrepreneur if she cannot hire new employees to work on that activity.

We can look at the short- and long-run growth effects of converging towards the performance levels of "target countries". The target groups include those countries which are found to be the 'best performers' in terms of education, product and labor market regulations. In order to determine these groups, we rank countries according to the variables SUP and PMR*LPE and we come up with two target groups: Non-European target group: USA and Canada; European target group: UK, Ireland and Denmark. The advantage of these two target groups is that they allow comparisons between countries within the European Union as well as with non European counterparts. Interestingly, we found the same target groups both for the higher education and the labor and product market regulation. Then we can assess the average effect of converging towards best practice for the eurozone (EMU) as a whole. Our results are that converging towards the best practice in terms of product and labor market liberalization generates a growth gain of between 0.3 and 0.4 already in the short run. Converging towards the best practice in terms of higher education enrollment generates a growth gain which is initially smaller (if we take the UK, Ireland and Denmark as the reference countries), but grows up to 0.6 by 2050. Altogether, a full percentage point in growth can be gained through structural convergence towards those three countries.

8.1.2 Rethinking the role and design of Structural Funds

Here we argue that structural funds can be partly reoriented towards facilitating the implementation of structural reforms. So far, these funds have been used mainly to finance medium-term investment projects and to fostering socio-economic cohesion within the EU. Moreover, these funds are allocated ex ante based on recipient countries' GDP relative to the EU average, population and surface.

We argue in favour of an alternative approach both to the goals, targeting and governance of Structural Funds. On the goals of Structural Funds: These funds should become transformative, in other words they should help achieve structural reforms in the sectors they are targeted to. In our above discussion, we identified some main areas (areas or sectors?) where structural reforms are needed: labor markets, product markets and education. Structural funds should aim at facilitating changes in the functioning of these sectors in the various countries. The allocation of funds should generally be made on an individual basis: in other words, they should mainly target schools, employment agencies, individual workers, not so much countries. The funds would help finance transition costs. The allocation of funds should be to well-specified deliverables (provision of better tutorship in education, improvements in the organization of employment agencies, transition to portable pensions rights across two or more countries, setting up of diploma equivalence for service jobs,...) and should be also conditional upon the country or region not having put in place a general policy that contradicts the purpose of the fund allocation.

Now regarding the governance of Structural Funds, the allocation of funds should be made by European agencies on the model of the European Research Council: bottom up approach with peer evaluation ex ante and ex post.

8.2   Rethinking industrial policy in the EU

Growth in the EU also requires adequate vertical targeting, both by member states and at EU level. In the previous sections we have emphasized the view that horizontal targeting should be given priority: basic and applied research, higher education, labor mobility. But, in light of our discussion in the previous sections, we also believe that well governed vertical targeting by member states and at EU level can help foster growth further within the EU.

At EU level, infrastructure investments in transportation, energy, and broadband network should greatly contribute to increasing product market competition in local markets. In other words, proper vertical targeting at EU level can help enhance horizontal policies in member states. Another justification for privileging vertical targeting at EU level, is that targeting at EU level is more likely to preserve product market competition when the targeted activities involve important fixed costs. What we mean here, is that subsidizing activities with high fixed costs at local level (i.e. at the level of one particular country) often boils down to subsidizing one particular firm, which in turn defeats the purpose of reconciling industrial policy with the need to enhance product market competition. This consideration becomes less binding when vertical targeting is done at EU level, since at EU level it is easier to find more than one potential recipient of vertical subsidies, including for activities involving high fixed costs.

But EU policy with regard to vertical targeting goes beyond EU level investments: it also concerns the attitude of the European Commission with regard to sectoral policies by member states. These are currently perceived by European authorities as a threat to European integration which in turn explains the fussy checks by European competition authorities of all devices supporting industrial activities. Here, let us mention a remarkable work on state aid in Europe, Japan and the United States by Pierre-André Buigues and Khalid Sekkat which identifies false debates and arguments against industrial policy. These authors find a general tendency in Europe towards lowering state aid (Germany being an exception, although mainly since the past ten years with the integration of the Eastern landers). This in turn suggests that the Commission has been remarkably effective in limiting the scope of state aid. What we recommend is to have the Commission become less a priori biased against the use of state aid while at the same time setting new and clear guidelines for the allocation and governance of that aid. In other words, the Commission should move from an "ex ante", legalistic, approach to sectoral state aid to an "ex post", pragmatic, approach where state aid is sanctionned only when it can be proved that it resulted in lowering product market competition in the corresponding activity.

Whether at EU level or by member states, vertical targeting should be adequately designed and governed. In the previous section we mentioned the recent paper by Nunn and Trefler (2009) suggesting that sectoral aid is more likely to be growth-enhancing if it target sectors with higher growth potential, one measure of it being the extent to which various industries are skill-biased. We also mentioned the work by Aghion et al (2013) suggesting that vertical targeting is more growth-enhancing if it targets activities with higher degree of product market competition and enhance product market competition within the sector.[28]

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[28] While it is part of the EU mission to promote product market competition, at the same time, natural monopolies are prevalent in network sectors, and having too many networks, may result in Europe becoming underequipped in the field of broadband optics and more generally disadvantaged in digital industry activities. This consideration should of course be also taken into account when designing vertical targeting at EU level.

8.3 More flexible macroeconomic policies at EU level

In previous sections we have argued that more countercyclical macroeconomic policies can help (credit-constrained) firms maintain R&D and other types of innovation-enhancing investments over the business cycle. One implication of this for European growth policy design, is that all the debt and deficit targets (both in the short and in the long term) should be corrected for cyclical variations, in other words they should always be stated in structural terms. Thus, for example if a country's current growth rate is significantly below trend, then the short run budgetary targets should be relaxed so as to allow this country to maintain its growth enhancing investments. However, while the fiscal compact specifies long-term objectives that are stated in structural terms, the short and medium term targets agreed between the European Commission and member states last year, are in nominal terms. This inconsistency is damageable to growth.

9   Conclusion

In this paper we have tried to show how theoretical models of growth and innovation can deliver testable predictions and also policy recommendations. Our emphasis has been on the Schumpeterian approach where each innovation induces positive knowledge spillovers on subsequent research but also destroys rents from previous innovations.

Where do we see the research on R&D, innovation and growth being pushed over the next years? A first direction is to look more closely at how growth and innovation are affected by the organization of firms and research. Thus over the past five years Nick Bloom and John Van Reenen have popularized fascinating new data sets that allow us to look at how various types of organizations (e.g. more or less decentralized firms) are more or less conducive to innovation. But firms' size and organization are in turn endogenous, and in particular they depend upon factors such as the relative supply of skilled labor or the nature of domestic institutions.

A second and related avenue for future research is to look in more details at innovation-led growth, firm dynamics and reallocation in developing economies. Recent empirical evidence (see Hsieh and Klenow 2009, 2012) has shown that misallocation of resources is a major source of productivity gap across countries. What are the causes of misallocation, why do these countries lack *creative destruction* which would eliminate the inefficient firms? Schumpeterian theory with firm dynamics could be an invaluable source to shed light on these important issues that lie at the core of the development puzzle.

A third avenue is to look at the role of finance in innovation-led growth. Recent studies point at equity finance being more growth-enhancing in more frontier economies. More generally, we still need to better understand how different types of financial instruments map with different sources of growth and different types of innovation activities. Also, we need to better understand why we observe a surge of finance during the acceleration phase in the diffusion of new technological waves, and also how financial sectors evolve when the waves taper off.

A fourth avenue is to analyze in greater depth the relationship between innovation, income inequality and social mobility, and to gather new data on individual patenting and revenues to look at how taxation policy affects the flow and nature of innovation and the mobility of innovators. These and many other microeconomic aspects of innovation and growth await further research.

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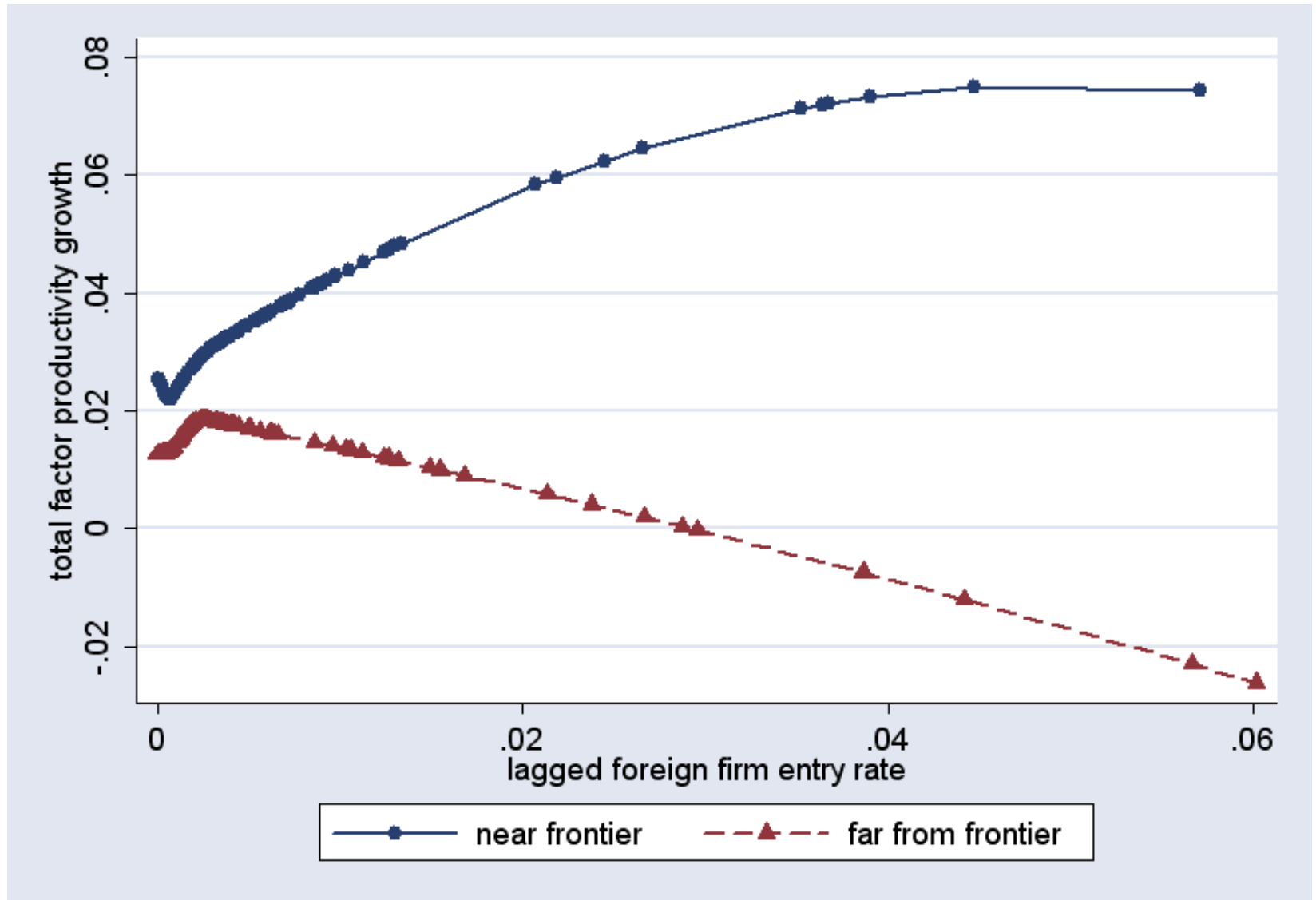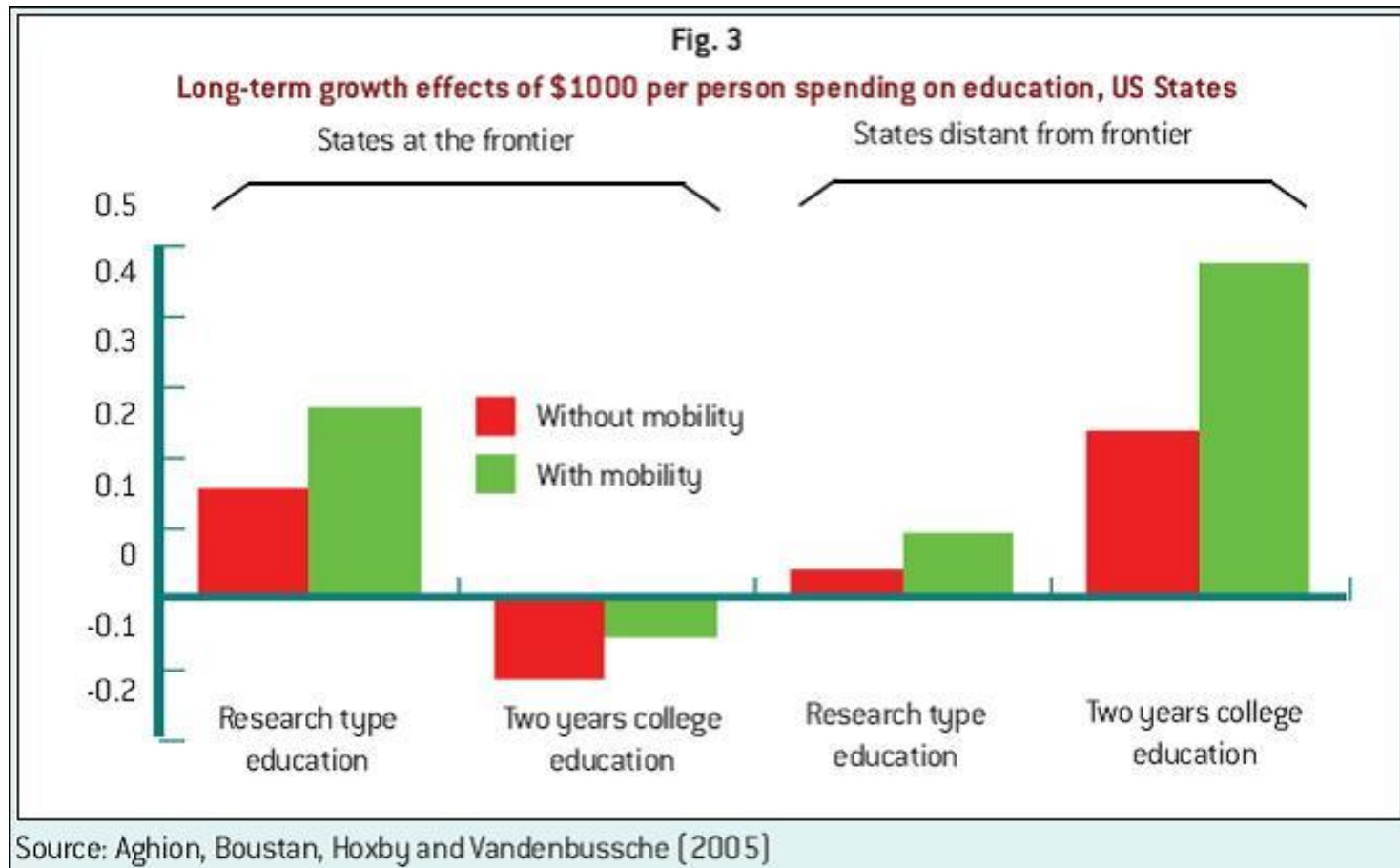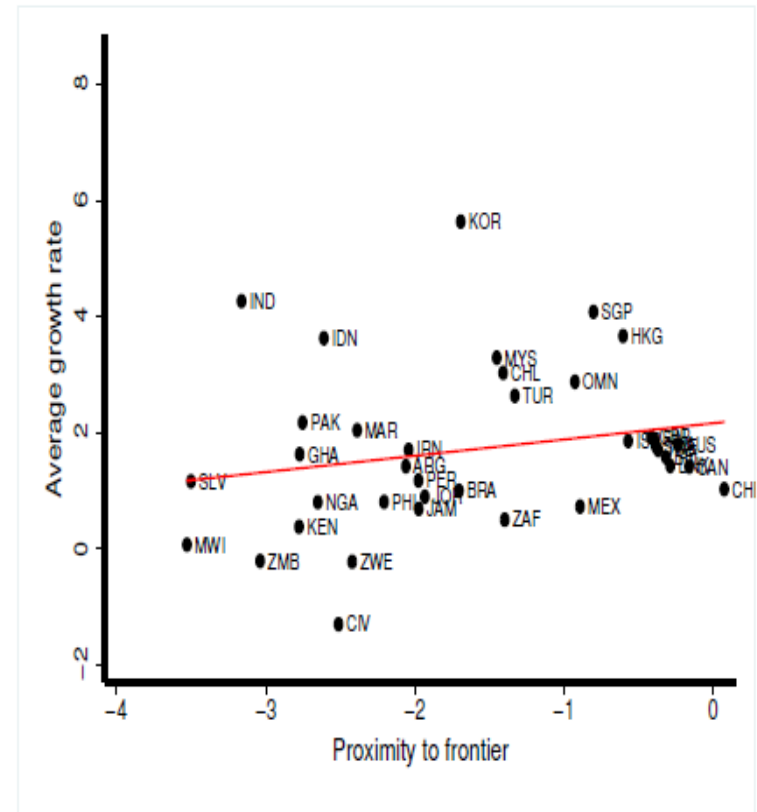
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Figure 1

Figure 2

Fig. 3
Long-term growth effects of $1000 per person spending on education, US States

States at the frontier — States distant from frontier

Without mobility
With mobility

Research type education — Two years college education — Research type education — Two years college education

Source: Aghion, Boustan, Hoxby and Vandenbussche (2005)
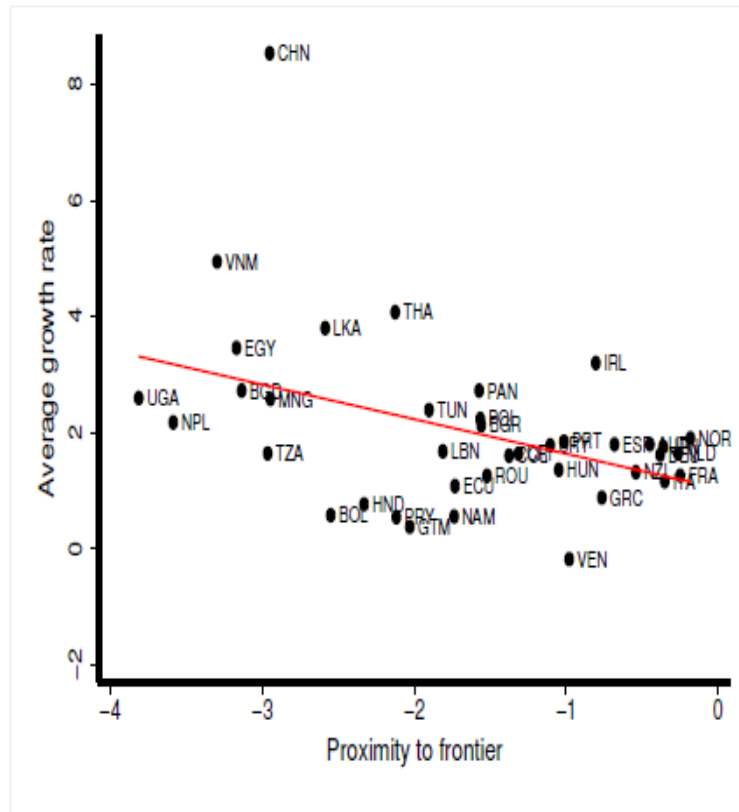
Figure 3

Figure 1: Average growth rate and Proximity to the frontier for the Bank-Based (left) and Market-Based (right) countries (per capita GDP growth rate)

Figure 4

Legend: Granted patent per 1000 inhabitants --- Top 1% income share

Figure 5

Number of patents per 1000 inhabitants — Top 1% income share
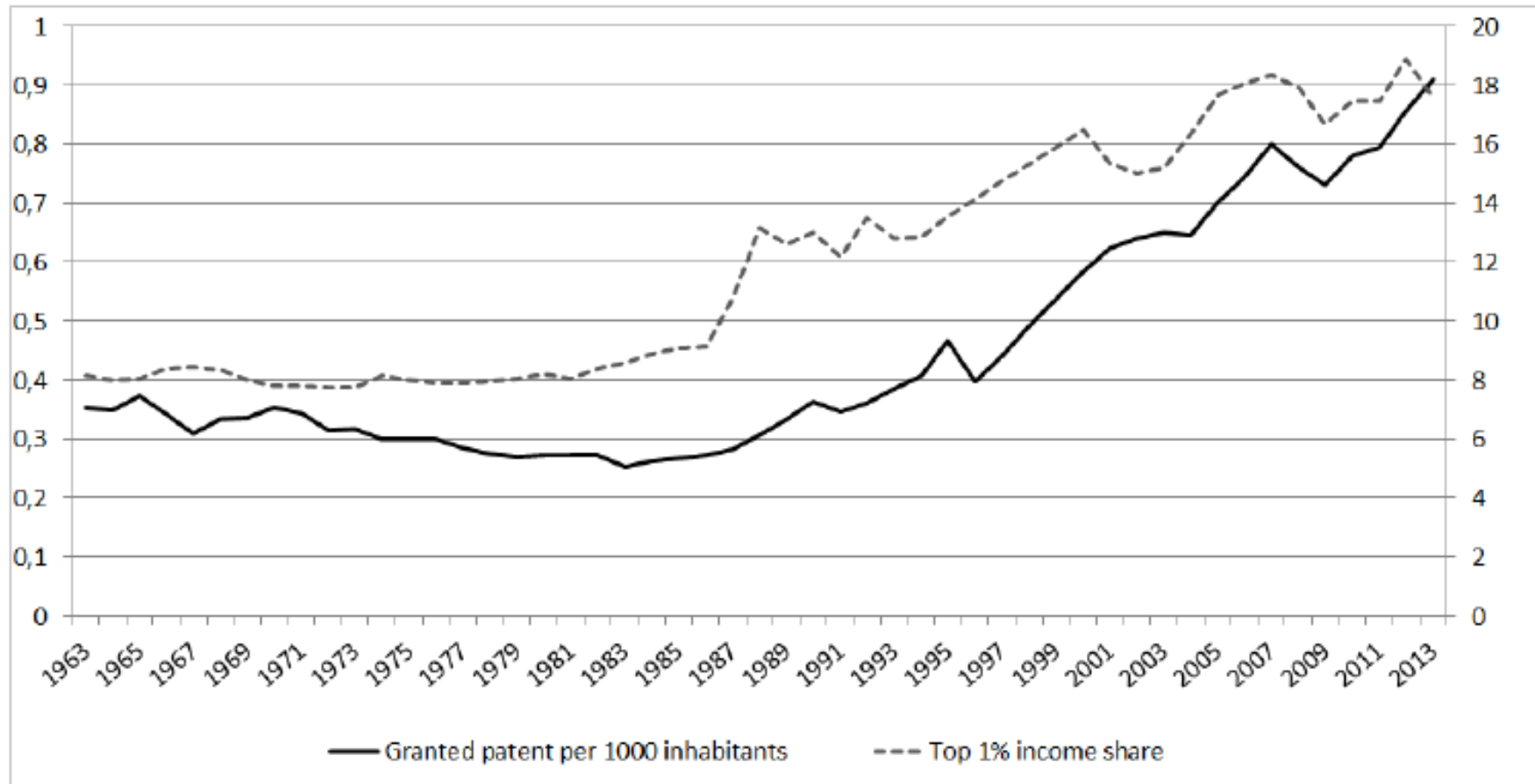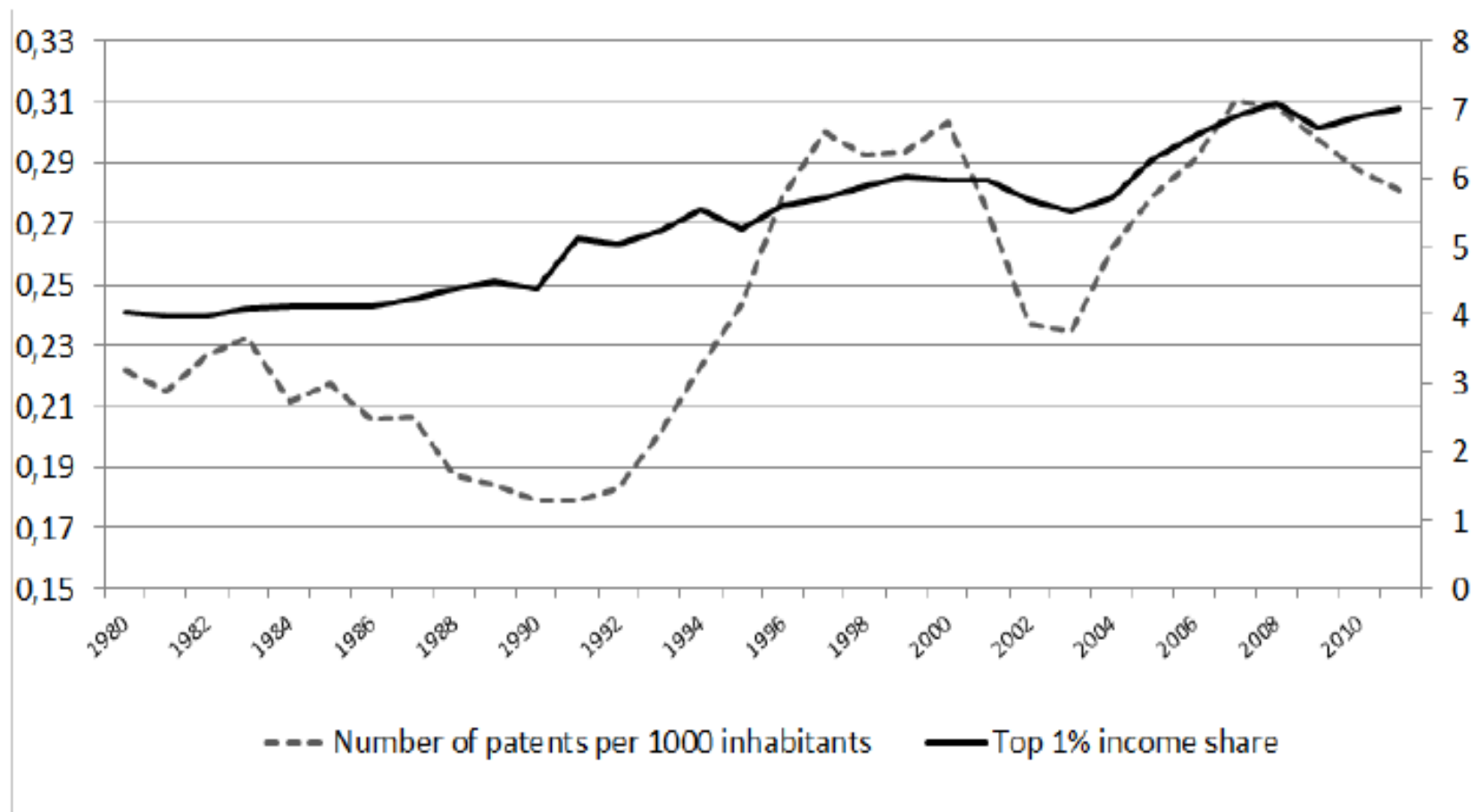
Figure 6

Delayed productivity growth waves in other countries

HP filtering of TFP growth with λ=500
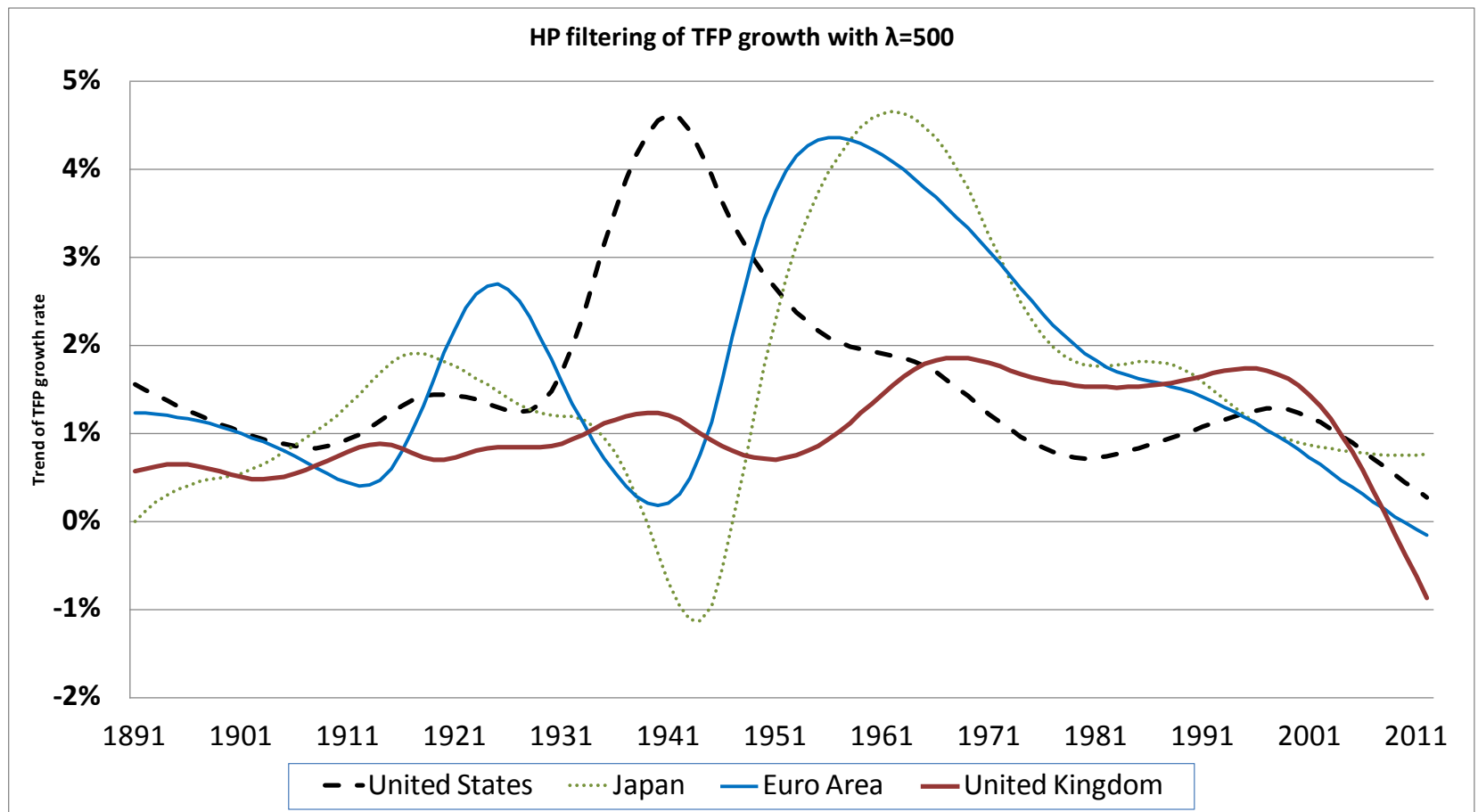
Figure 7
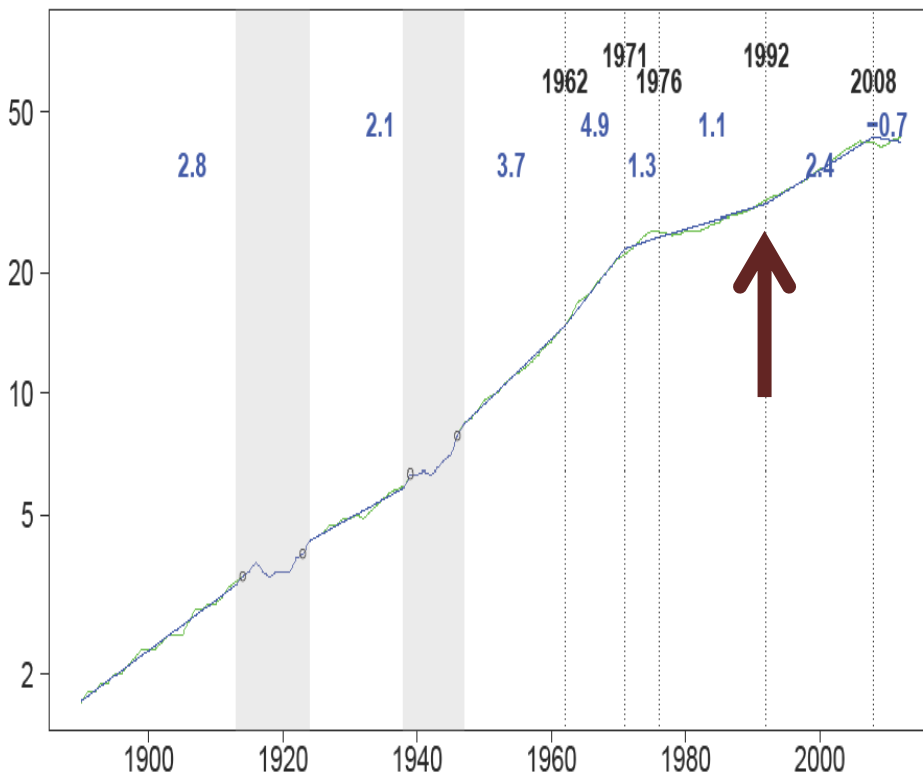
Productivity breaks:
country-specific shocks
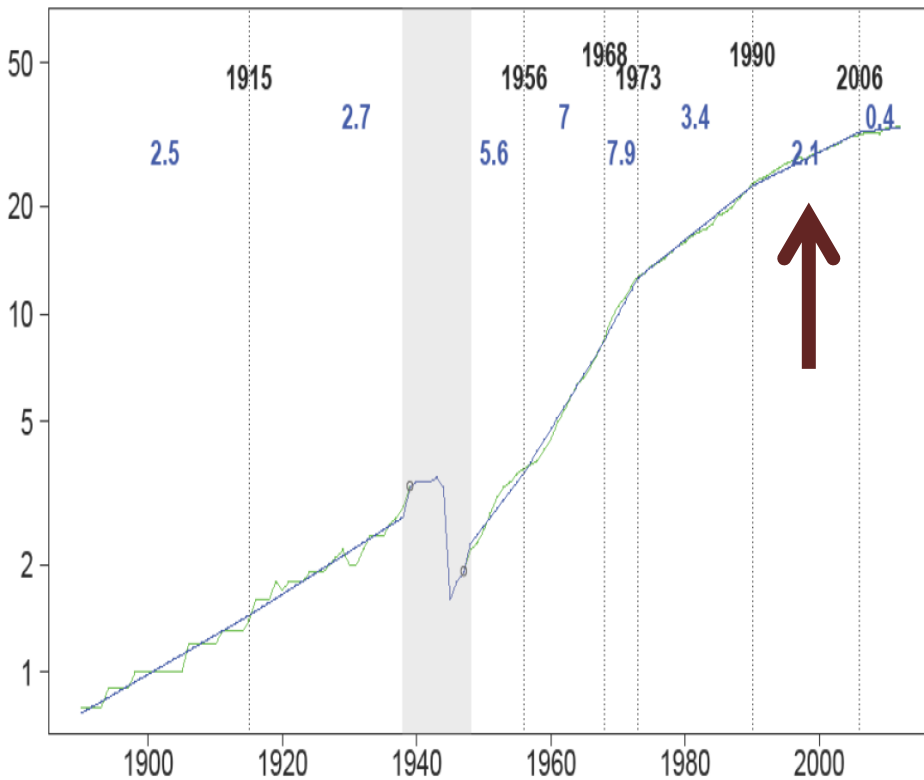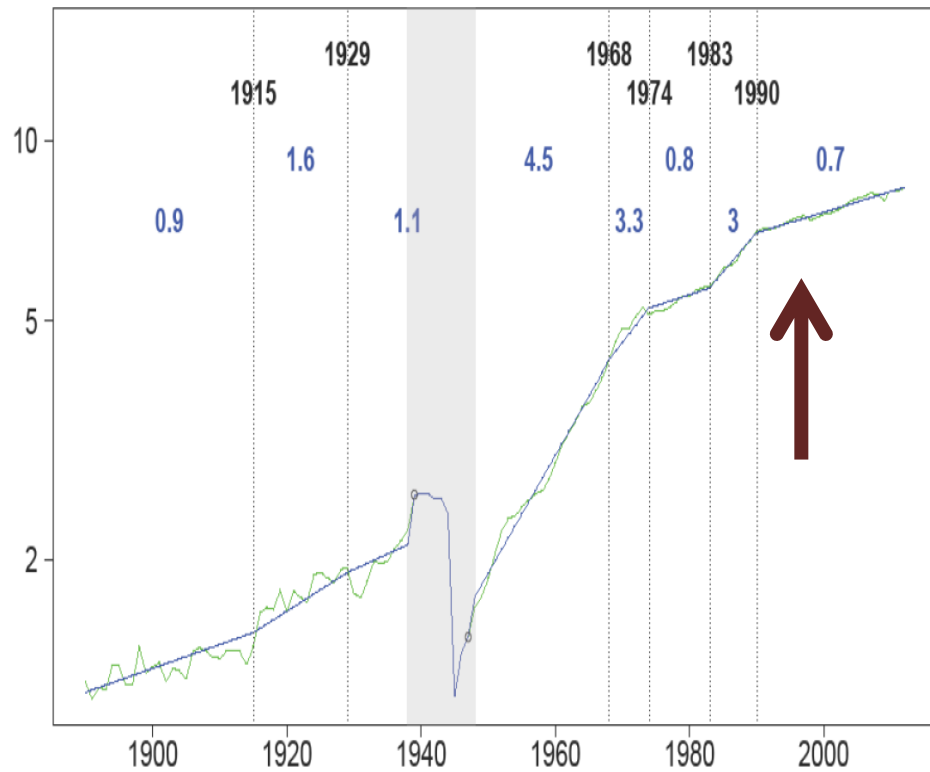Sweden

Figure 8

Productivity breaks:
country-specific shock

Japan

Labor productivity   **Total Factor Productivity**
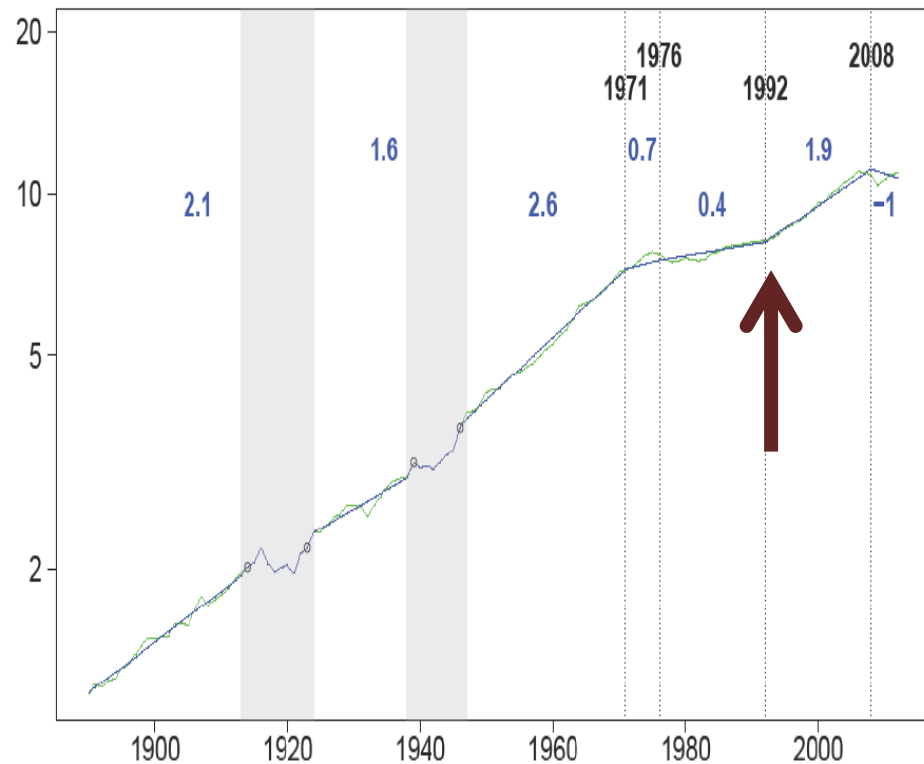
US$ PPP of 2005 (log scale)
Areas in grey: war periods

Panel : Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Iceland, Italy, Japan, Korea, the Netherlands, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States.

Times period : 1995-2007

Dependant variable : Hourly labour productivity growth (instrumental variables method)

	(1)	(2)	(3)	(4)	(5)
Changes in capacity utilization rate	0.00200*** (0.000622)	0.00190*** (0.000499)	0.00161*** (0.000475)	0.000908 (0.000648)	0.000634 (0.000702)
Growth in working time	-0.583*** (0.170)	-0.787*** (0.138)	-0.797*** (0.138)	-0.784*** (0.157)	-0.698*** (0.172)
Changes in the employment rate	-0.529*** (0.177)	-0.641*** (0.165)	-0.653*** (0.160)	-0.878*** (0.203)	-0.809*** (0.217)
Share of ICT production in total VA	0.930*** (0.261)	0.344* (0.195)	0.372** (0.179)	0.0614 (0.164)	0.170 (0.178)
Share of pop. (>15) w/ some higher educ.		0.0808** (0.0348)			
EPL			-0.00726** (0.00307)		
PMR(t-2)				-0.0103** (0.00486)	
EMPL* PMR(t-2)					-0.00368*** (0.00130)
Constant	-0.0376** (0.0160)	-0.0199 (0.0153)	0.0107 (0.0118)	0.0296** (0.0137)	0.0197* (0.0113)
Observations	163	149	142	95	95
P-value of the Durbin-Wu-Hausman endogenity test	0.00066	0.02912	0.03388	0.02966	0.01112
P-value of Basmann test of overidentifying restrictions	0.6354	0.2581	0.4140	0.2075	0.7716

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1