

1 Innovation and Growth: The Schumpeterian Perspective

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Abstract

This chapter shows how the Schumpeterian growth paradigm can be used both to shed light on various aspects of the growth process which cannot be easily understood using alternative paradigms, and also to think about policies to foster innovation-led growth in a developed economy. In particular it will: (i) look at the relationship between growth and competition; (ii) shed light on how growth relates to firm dynamics and the size distribution of firms; (iii) revisit the debate on how growth relates to income inequality and social mobility; and (iv) discuss the role of the state in fostering innovation-led growth, and question the design and limits of R&D subsidies, or the desirable scope for patent protection, or whether the government should provide sectoral state aids or instead limit itself to pure horizontal targeting.

1.1 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 chapter 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 the theoretical and empirical background to think about growth policy design in EU countries.

We should emphasize right away that this chapter 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. Why do we need competition policy for innovation-led growth?
2. How does growth relate to firm dynamics and the size distribution of firms?
3. Does growth increase or reduce unemployment?
4. What distinguishes innovation-led growth from other types of growth? What are the main drivers of innovation-led growth?
5. How can macroeconomic policy help sustain innovation-based growth? Should we oppose structural reforms and the need for (more flexible) macroeconomic policy to enhance innovation-led growth?
6. What is the relationship between innovation-led growth, inequality and social mobility?
7. Should this relationship 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?
8. How should we reform the welfare state in order to facilitate innovation-led growth?
9. Should governments subsidize R&D to foster innovation-led growth: is such government intervention necessary or sufficient?
10. What are the limits to patenting and intellectual property and why do we need academic freedom and openness?

The remaining part of this chapter will be organized as follows. Section 1.2 will succinctly present the main growth paradigms. Section 1.3 will present some of the main distinctive predictions of the Schumpeterian growth paradigm. Section 1.4 will discuss growth policy design in advanced countries. Section 1.5 will talk about technological waves and will touch upon the debate on secular stagnation. Section 1.6 will provide Schumpeterian insights into the design of R&D policy. Section 1.7 will analyse the role for openness and freedom in a multistage process of innovation. Section 1.8 will build on the policy discussion in this survey to revisit the issue of how to bring Europe back into a high growth path. Finally Section 1.9 will conclude the survey.

1.2 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.

1.2.1 *The Neoclassical Growth Model*

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

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

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. Thus the model cannot explain long-run economic growth, it can just predict that faster capital accumulation (through increasing the savings rate) will boost growth temporarily.

To analyse policies for long-run growth, one needs a theoretical framework in which productivity growth is endogenous; that is, dependent upon characteristics of the economic environment. This framework must account for long-term technological progress and productivity growth, without which diminishing marginal productivity would eventually choke off all growth.

1.2.2 *The AK Model*

The first version of endogenous growth theory is the so-called AK theory,¹ 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 at 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.

1.2.3 *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. A first branch within this new class of endogenous growth models 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 of technology spillovers.

It starts from a Dixit and 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 about 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.

1.2.4 The Schumpeterian Model

The second branch in this new wave of (innovation-based) endogenous growth models is the Schumpeterian paradigm (see Aghion and Howitt, 1992, 1998). This paradigm 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., labour 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, etc. This propensity to underinvest is reinforced by the existence of credit market imperfections which become particularly tight in recessions.

Hence there is 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 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 labour 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:

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

where A_{it} is a productivity parameter attached to 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 (respectively insufficient) under laissez-faire when the business-stealing effect associated with creative destruction dominates (respectively is dominated by) the intertemporal knowledge spillovers from current to future innovators.²

1.3 Some Main Applications and Extensions of Schumpeterian Growth Theory

1.3.1 *Growth Meets IO*

Both empirical studies³ 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 assume 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's (1992) model as well, 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.⁴ Namely, a firm that is currently behind the technological leader in the same sector or industry must 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 2 *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 if we take a picture of the overall economy at any point in time, we will observe that most sectors in the economy are neck and neck; 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 if we take a picture of the overall economy at any point

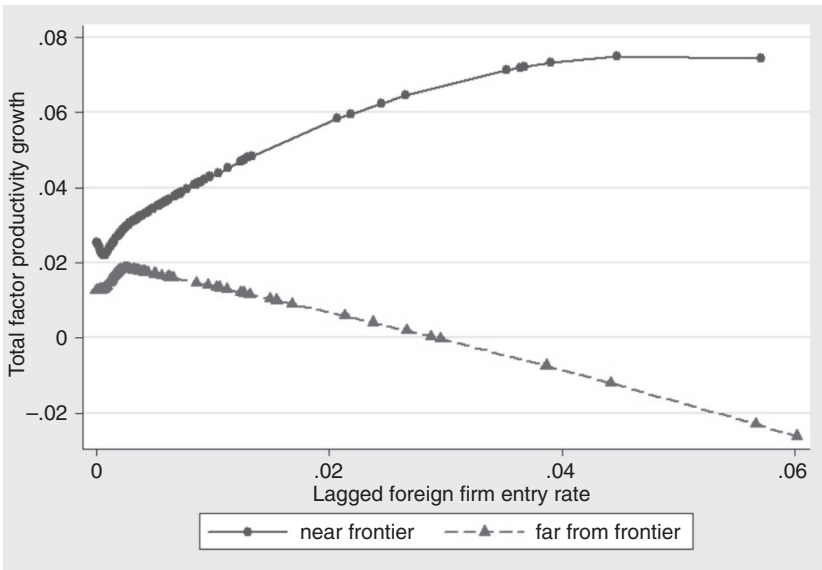


Figure 1.1 Entry effects near and far from the technological frontier (Aghion et al., 2009b).

in time we will see that most sectors in the economy are unleveled sectors, so that the Schumpeterian effect dominates overall. This inverted-U prediction is confirmed by Aghion et al. (2005a), using panel data on UK firms.

Prediction 3 *More intense competition enhances innovation in ‘frontier’ firms but may discourage it in ‘nonfrontier’ firms.*

Intuitively, a frontier firm can escape competition by innovating, unlike a nonfrontier firm who can only catch up with the leader in its sector. This prediction is tested by Aghion et al. (2009c) again using panel data of UK firms. Figure 1.1 below (from Aghion et al., 2009b) shows how competition (here measured by the lagged foreign entry rate) affects productivity growth in domestic incumbent firms. The upper curve shows 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*’, that is, 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 product market competition is.

Prediction 4 *There is complementarity between patent protection and product market competition in fostering innovation.*

Intuitively, competition reduces the profit flow of noninnovating 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.⁵ This prediction is confirmed by Aghion et al. (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).

1.3.2 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; and (iii) small firms exit more frequently, but the ones that survive tend to grow faster than the average growth rate.

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’.⁶

However, 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.⁷

This model allows us to explain the above stylized facts:

Prediction 5 *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 time survived many attempts by potential entrants

and other incumbents at taking over its existing lines, in order to become a large firm. This explains why there are so few very large firms in steady-state equilibrium, that is, why firm size distribution is highly skewed as shown in a vast empirical literature.

Prediction 6 *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.⁸

Prediction 7 *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 exit, whereas it takes two successful innovations by potential entrants to make a two-product firm exit. The fact that small firms exit more frequently and grow faster conditional on survival have been widely documented in the literature.⁹

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 analysing how institutional development (or the lack of it) affects firm size distribution and firm dynamics.

1.3.3 *Growth Meets Development: Appropriate Institutions*

In Section 1.3.1 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 modelling 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 the innovating sector i , which is some multiple γ of its preexisting value. And it also encompasses the case of an innovation that catches up to a global technology frontier \bar{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.

One can thus naturally capture Gerschenkron's idea¹⁰ of 'appropriate institutions'. Namely, far from the frontier a country will maximize growth by favouring 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 frontier innovation for growth is also increasing. Institutions which favour innovation-led growth include graduate schools, competition enforcement, labour market flexibility and financial sectors which emphasize equity financing.

Thus Acemoglu et al. (2006) (Acemoglu-Aghion-Zilibotti, henceforth AAZ), provide support to the following predictions using a cross-country panel of more than 100 countries over the 1960–2000 period. Using Frankel and Romer's (1996) measures of openness (namely exports plus imports divided by GDP and instrumented using geographical and regulatory variables), they show:

Prediction 8 *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 9 *High entry barriers become increasingly more 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 10 *The more frontier an economy is, the more growth in this economy relies on research education.*¹¹

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.¹² To the extent that innovation matters more for growth in more frontier economies, the prediction is:

Prediction 11 *The correlation between democracy and innovation (or growth) is more positive and significant, the closer the country is to the frontier.*

This prediction is confirmed by Aghion et al. (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 labour 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, etc.) are better suited to the needs of an innovative firm at 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.

1.3.4 Growth Meets Development: 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.

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 et al. (2014b) (Akcigit-Alp-Peters, henceforth AAP) 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; and (ii) firm owners can be of two types, high or low. High-type firms are more creative and have the potential to expand 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 12 *Everything else equal, the probability of hiring an outside manager and, conditional on hiring, the number of outside managers is increasing with firm size, and increasing with the rule of law.*

Larger firms operate with more product lines and hence 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 13 *Average firm size increases with the rule of law.*

Firm value is increasing with owner time and therefore the firms are willing to innovate and expand more when firm value is higher. The positive link between firm size and the rule of law has been extensively documented in the literature (see for instance Bloom et al. (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 14 *Firm growth decreases in firm size, and the 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 to each product line and hence the frictions to delegate 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 15 *Everything else equal, creative destruction and the reallocation among firms will be much higher in economies where the rule of law is stronger.*

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.

1.3.5 *Growth and Unemployment*

Peter Diamond, Dale Mortensen and Christopher Pissarides received their Nobel Prize in Economics for their research on ‘markets with search frictions’. Their research was centred 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.¹³

And indeed the Schumpeterian growth paradigm allows us to analyse the implications of frictional matching on the labour 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, that is, 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 16 *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.*

The intuition is simply that when the rate of job destruction is small, then innovation is the main source of job destruction and job destruction is immediate, whereas job creation happens later due to the labour market frictions.

Prediction 17 *When the rate of exogenous job destruction is high, then the relationship is negative growth and unemployment: in this case the job creation effect of innovation-led growth on unemployment dominates the job destruction effect.*

This framework is used by Aghion et al. (2015b) to analyse the relationship between innovation-led growth and well-being. On the one hand, more creative destruction implies more job destruction, 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.

1.4 Enhancing Productivity Growth in Advanced Countries

1.4.1 Pillars of Innovation-Led Growth

In the previous section we explained why institutions and policies to enhance productivity growth should differ between countries at the world technology frontier and countries that are farther behind the frontier. In particular we saw that competition is more growth enhancing in sectors or countries that are closer to the technological frontier. Similarly, Aghion et al. (2005b) show that more flexible labour markets (which facilitate the process of creative destruction) foster greater productivity growth in more advanced countries.

A third lever of productivity growth in advanced countries is graduate education: indeed frontier innovation requires frontier researchers and therefore good universities and research centres, whereas good undergraduate education is sufficient for imitation. Figure 1.2, drawn from Aghion et al. (2009c). Shows that research education enhances productivity growth more in more frontier US states, that is, in states with a higher per capita GDP (California, Massachusetts, ...): these are states where a higher fraction of firms are 'frontier-firms', that is, 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 Vandebussche et al., 2006).

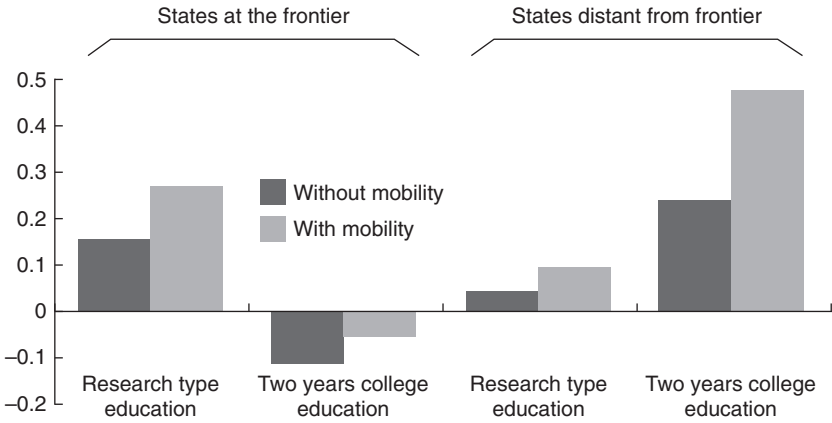


Figure 1.2 Long-term growth effects of \$1000 per person spending on education, US states (Aghion et al., 2005b).

A fourth lever of productivity growth is the organization of the financial sector. As shown by Figure 1.3 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 that breaks new ground entails a higher level of risk than imitation activities, which are already well defined. But this in turn implies

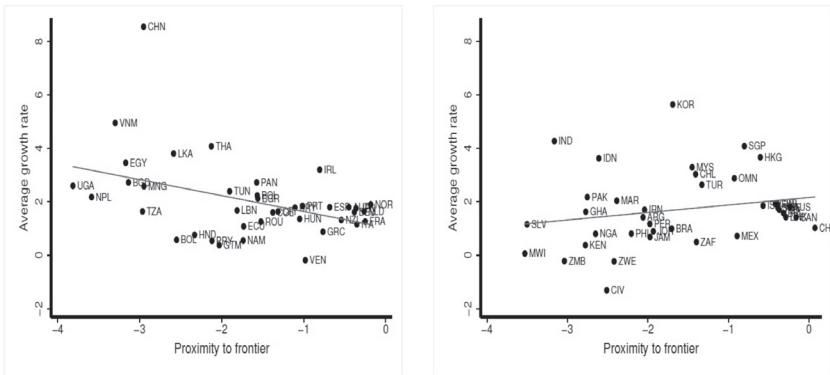


Figure 1.3 Average growth rate and proximity to the frontier for the bank-based (left) and market-based (right) countries (per capita GDP growth rate, Koch, 2014).

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.

1.4.2 *Competition Policy against Industrial Policy*

Should sectoral policies always be precluded if we (justifiably) believe in the virtues of competition for innovation-led growth? 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 firms¹⁴; (ii) *the criteria underlying the selection of activities are clear and verifiable*: in particular, recent research¹⁵ points at skill-intensity and the degree of product market competition as relevant selection criteria for vertical targeting; and (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 nonperforming activities.

First empirical support for rethinking sectoral policy is provided by Nunn and Trefler (2010). These authors use micro data on a set of countries to analyse whether, as suggested by the argument of ‘infant industry’, the growth of productivity in a country is positively affected by the measure in which tariff protection is biased in favour 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 per cent 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 et al. (2015c) 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, etc.) 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 Total Factor Productivity (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. (2015c), 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 1.5 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. (2015a) explore a cross-country panel dataset 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. (2015a) 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 reallocation 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.

1.4.3 *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 defence, 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, that is, 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 favour 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 adopting a new approach to public spending: in particular, they must depart from the Keynesian policies aimed at fostering growth through 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 is 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, labour market policies and support to labour and product market flexibility; industrial sectors with high growth potential and externalities as we argued above.

1.4.4 *Macroeconomic Policy*

Recent studies (see Aghion et al., 2009a, 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, etc.) 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 neoliberal policy of just minimizing tax and public spending in recessions.

Note that such policies are complementary to the above-mentioned structural policies aimed at favouring innovation-led growth, namely product market liberalization, labour 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 labour market.

1.4.5 *Innovation, Inequality, and Social Mobility: Making Growth Inclusive*

Figures 1.4 and 1.5 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 50 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 1970s and then sharply increasing since the early 1980s.

Does this 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 per cent income share in the US state is positively and significantly correlated with the state's degree of innovativeness, that is, with the quality-adjusted

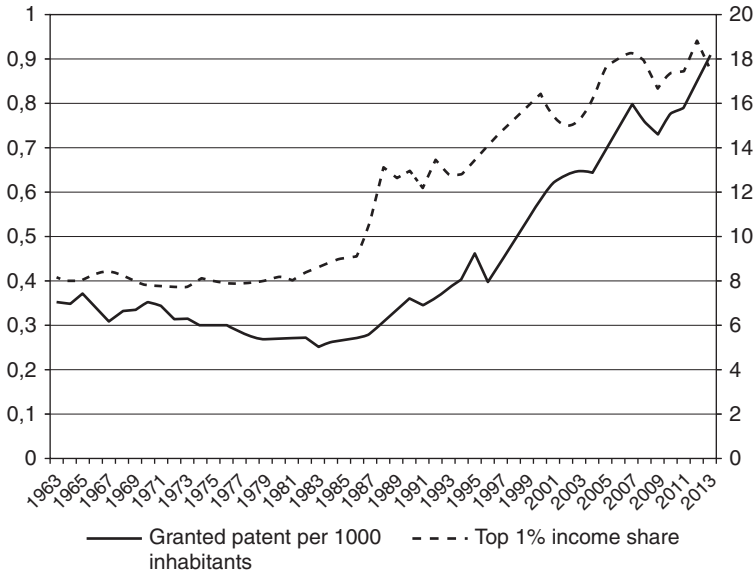


Figure 1.4 Evolution of the top 1 per cent income share and of the total patent per capita in the US (Aghion et al., 2015d).

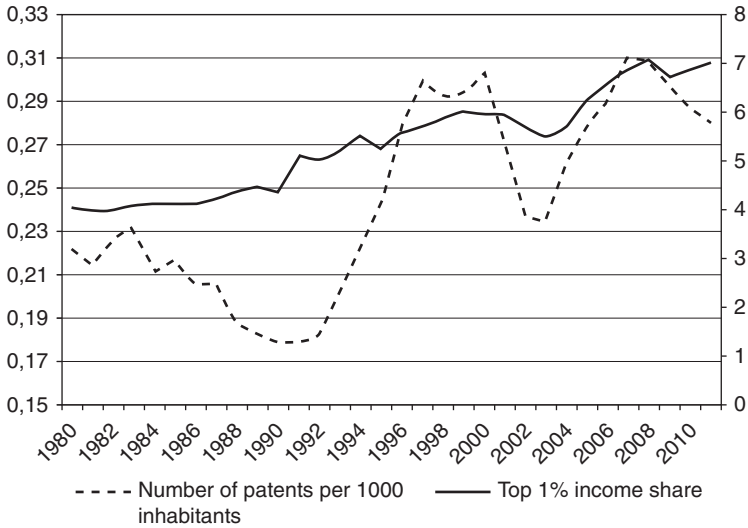


Figure 1.5 Evolution of the top 1 per cent income share and of the total patent per capita in Sweden (Aghion et al., 2015d).

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 inequality¹⁶ (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 2–10 per cent 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 mobility; and (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 labour market liberalization, which enhance productivity growth as we have argued above, also increase social mobility to the extent that they favour innovation and creative destruction.¹⁸ Thus the three pillars of an innovation-led growth strategy, namely (higher) education, product market flexibility, and labour 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 labour 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 labour income, and a second time when they collect revenues from saving their net labour 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 labour income). An analysis of optimal taxation policy in the context of an innovation-led economy is beyond the scope of this chapter 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 acknowledged that by deciding to: (i) lower its maximum tax rate on labour

income from around 90 per cent before 1991 to 57 per cent after 1991; and (ii) move from a progressive tax schedule on capital income with a maximum marginal tax rate at 72 per cent before 1991 to a flat rate of 30 per cent 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.

1.5 Technological Waves and the Debate on Secular Stagnation

1.5.1 *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; and (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 debts that add to government debts. We disagree with this pessimistic 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 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 slowdown in the contribution of IT to productivity growth, can be due to measurement problems: in particular Byrne et al. (2013) 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 is another consideration, made by Bergeaud et al. (2014), which directly links to the focus of this chapter: 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 labour market liberalization) required for a successful transition to innovation-based growth.

1.5.2 *Historical Wave Patterns*

In the remaining part of this section we take a brief look at technological waves and their diffusion from the 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 are defined as generic technologies which affect most sectors of the economy. Obvious examples include steam energy in the early and mid nineteenth century, electricity and chemistry in the early twentieth 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.

Two Productivity Growth Waves

Using annual and quarterly data over the period 1890–2012 on labour productivity and TFP for 13 advanced countries (the G7 plus Spain, The Netherlands, Finland, Australia, Sweden and Norway) plus the reconstituted Euro area, Bergeaud et al. (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. The second wave is the ICT wave. This wave is of smaller magnitude than the first one, and a big question is whether it has ended in the US.

Diffusion Patterns

Figure 1.6 from Cette and Lopez (2012) shows that the Euro Area²⁰ and Japan suffer from a lag in the diffusion of technological waves compared 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.

And through an econometric analysis, Cette and Lopez (2012) show that this lag of ICT diffusion in Europe and Japan, compared 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

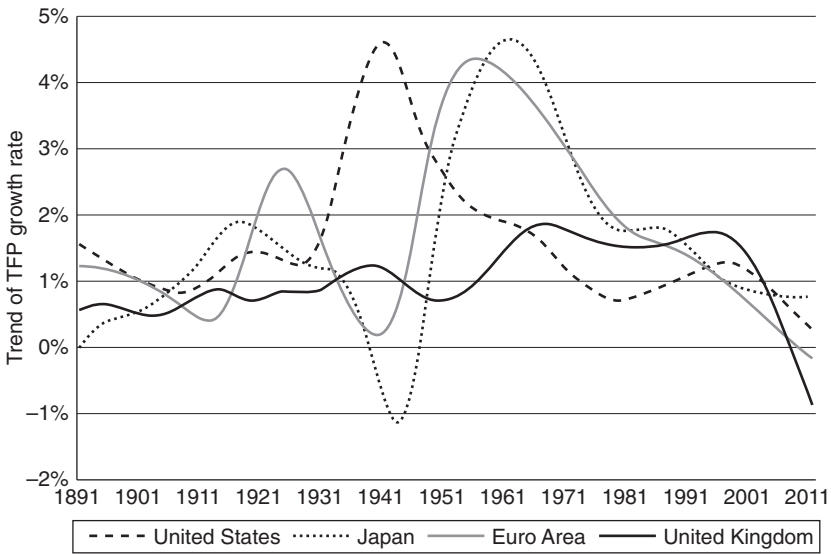


Figure 1.6 Delayed productivity growth waves in other countries. HP filtering of TFP growth with $\lambda = 500$ (Cette and Lopez, 2012).

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.

Country-specific Shocks and the Role of Reforms

Figure 1.7 from Bergeaud et al. (2014) shows a positive break in labour productivity and in TFP growth in Sweden after 1990. This stands in contrast with

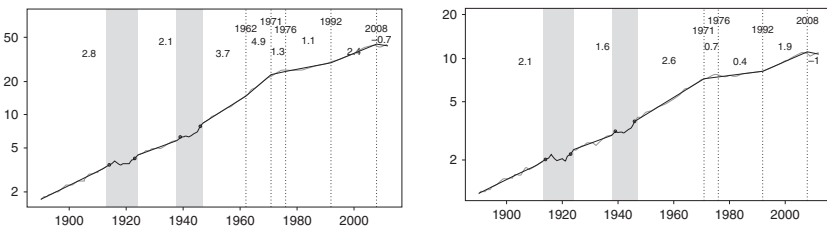


Figure 1.7 Productivity breaks: country-specific shocks (Sweden), labour productivity (left), total factor productivity (right). US \$ PPP of 2005 (log scale). Areas in grey: war periods (Bergeaud et al., 2014).

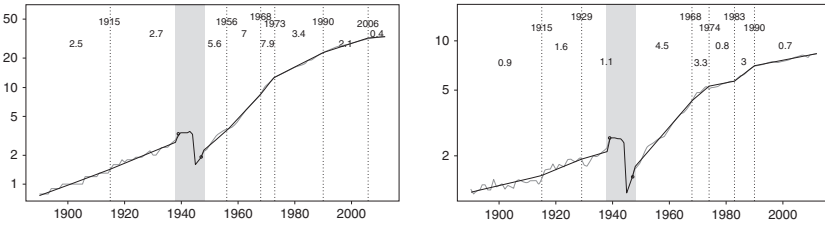


Figure 1.8 Productivity breaks: country-specific shocks (Japan), labour productivity (left), total factor productivity (right). US \$ PPP of 2005 (log scale). Areas in grey: war periods (Bergeaud et al., 2014).

the case of Japan shown in Figure 1.8: 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 30 years.

Let us consider from Bergeaud et al.'s (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 per cent over the period 1976–1992 to an average of 1.9 per cent over the period 1992–2008. Similarly, the 1982 reform (Wassenaar agreement) in the Netherlands is associated with a break from an average TFP growth rate of 0.5 per cent over the period 1977–1983 to an average TFP growth rate of 1.5 per cent 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 per cent over the period 1974–1990 to an average rate of 1.1 per cent 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 per cent to an average growth rate of 1.4 per cent 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.

1.6 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 US 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.

1.6.1 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 et al. (2000, 2006) have shown empirically that the reallocation of factors across firms accounts for more than 50 per cent 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). In particular Acemoglu et al. (2013) use 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 being both more R&D intensive

and growing 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 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, that is, 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 behaviour, 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.

1.6.2 *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 (Joint Economic Committee (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 programmes 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 US government has aggressively promoted collaboration between universities and industrial researchers through specific funding programmes. 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 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 et al. (2014a) 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. (2014a) take an important step towards 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. (2014a) first test Nelson's (1959) view that 'firms which support research towards 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 microlevel 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 Nelson's 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. (2014a) 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 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 analyse 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 policy-maker is able to discriminate between types of research projects at the firm level, a difficult task in the real world.

The authors then analyse 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 per cent and 100 per cent 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.

1.7 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 *ex post* 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 multistage research lines. This leads us to revisit the role of intellectual property (IP) versus academic freedom and openness in the innovation process.

1.7.1 *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), Aghion

et al. (2008) (Aghion-Dewatripont-Stein, 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 multistage research line. The line starts with an initial idea. Then the idea is elaborated upon in stages, until it leads to a marketable product. Each stage on the research line requires one researcher, and that researcher succeeds with some 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 the idea from the previous stage, each researcher decides whether she would better enjoy following the practical strategy or the alternative strategy. If she is able to undertake her favoured strategy, she suffers no disutility from working. However, if the researcher has to undertake the strategy that she likes less, she suffers a positive disutility. ADS assume that the choice of the practical vs. the alternative strategy is *ex ante* noncontractible. In other words, one cannot write a contract that promises a bonus for following the practical strategy, because the nature of the work that the 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 and she always works on her preferred strategy. This implies that with positive probability the scientist will not work on the practical strategy, but on the alternative strategy.

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 higher wage in order to work under this '*manager-control*' regime. The researcher's 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, 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 – that is, real authority – over her research agenda, will depend upon how strongly she is monitored by the firm that employs her.

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; and (ii) it is optimal to grant more freedom to the researcher in the earlier stage of the research process. In other words, research firms endogenously become more hands on in later stages of research projects as the value of focus increases as one moves down the research line closer to the commercialization stage.

1.7.2 *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. 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.

1.7.3 *Evidence on the Limits of IP and the Role of Openness and Freedom*

The above model generates the following predictions:

Prediction 18 *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. (2008) 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 19 *More openness: (i) enhances research freedom; (ii) enhances the creation of new lines and (iii) enhances basic research.*

Murray et al. (2015) test the prediction that in a research setting characterized by a high level of intellectual freedom, greater openness does not only 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. (2015) 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's contribution to the field. In particular, Williams (2013) uses a fascinating dataset on the sequencing of the human genome to analyse 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 Williams (2013) and Murray et al. (2015) have in common that they both analyse the impact of nonpatent 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.

1.8 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 labour 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; and (iii) more flexible macroeconomic policies (budgetary and monetary) at EU level.

1.8.1 *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 labour market liberalization and

higher education reform, to foster long-run growth in 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 labour 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.

Assessing the Growth Effects of Structural Reforms

As in Aghion et al. (2005b) 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-year-old population having completed tertiary education (SUP); for product market: an OECD index assessing product market regulation (PMR); for labour market: an OECD index assessing the strictness of employment protection (LPE). In fact we focus on the interaction between these two rigidities, namely the variable $PMR \times LPE$, in the analysis of labour and product market reforms. Indeed, there are good reasons to believe the effects of liberalizing product markets are complementary to those of liberalizing labour 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 labour market regulations. In order to determine these groups, we rank countries according to the variables SUP and $PMR \times LPE$ 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 labour 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 labour 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.

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 foster 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 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 where structural reforms are needed: labour 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 except for infrastructures that help enhance competition. 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 pension rights across two or more countries, setting up of diploma equivalence for service jobs, etc.) 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.

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.

1.8.2 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, labour 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 networks 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 this 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 US 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 lands). 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 sanctioned 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 (2010), suggesting that sectoral aid is more likely to be growth-enhancing if it targets 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 enhances product market competition within the sector.²⁸

1.8.3 *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 damaging to growth.

1.9 Conclusion

In this chapter 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 not only 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 datasets 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 labour or the nature of domestic institutions.

A second and related avenue for future research is to look in more detail 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 analyse 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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Notes

1. A precursor version of the AK model is the Harrod-Domar model (see Aghion and Howitt, 1998). Frankel (1962) developed the first version of the AK model as we know it, i.e., with Cobb-Douglas production functions (in capital and labour) for firms and knowledge externalities driven by capital accumulation by firms. Romer (1986) developed an AK model similar to Frankel but where savings are determined by intertemporal utility maximization instead of just being a constant fraction of final output as in Frankel (1962).
2. 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).
3. E.g., see Blundell et al. (1995).
4. See Aghion et al. (1997, 2001).
5. 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 Akgicig (2012) for a general analysis of optimal patent protection in Schumpeterian models with step-by-step innovation.
6. In the product variety model, exit is always detrimental to growth as it reduces product variety.
7. Various versions of this framework have been estimated using micro-level data by Lentz and Mortensen (2008), Acemoglu et al. (2013), Garcia-Macia et al. (2014) and Akgicig and Kerr (2015).
8. For recent discussions, see Haltiwanger et al. (2010) and Akgicig and Kerr (2010).
9. See Akgicig and Kerr (2010) and Aghion et al. (2014) for references. In a recent work, Acemoglu et al. (2013) analyse 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.
10. See Acemoglu et al. (2006) for a formalization of this idea.
11. Aghion et al. (2005b) 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 et al. (2006) show that tertiary education is more positively correlated with productivity growth in countries that are closer to the world technology frontier.
12. 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.
 13. See Aghion and Howitt (1994) and Mortensen and Pissarides (1998).
 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, etc.
 15. E.g., by Nunn and Trefler (2010), and Aghion et al. (2015c) which we summarize below.
 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.
 17. In Sweden for example, the Gini has not increased over the past 25 years, whereas both patenting and top income inequality have.
 18. See Aghion and Roulet (2014).
 19. See Bresnahan and Trajtenberg (1995).
 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, 88.5 per cent or the total GDP of the Euro Area.
 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 of -0.04 and innovation intensity (number of innovations relative to the firm size) on log firm size and find an estimate of -0.18 .
 23. http://jec.senate.gov/public/?a=Files.Serve&File_id=29aac456-fce3-4d69-956f-4add06f111c1.
 24. See Akcigit et al. (2014a) 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.
 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.
 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 nonprofit research mice repository.
 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.

References

- Acemoglu, D., and Acikcigit, U. 2012. Intellectual Property Rights Policy, Competition and Innovation. *Journal of the European Economic Association*, **10**, 1–42.
- Acemoglu, D., and Robinson, J. 2006. Economic Backwardness in Political Perspective. *American Political Science Review*, **100**, 115–131.
- Acemoglu, D., Aghion, P., and Zilibotti, F. 2006. Distance to Frontier, Selection, and Economic Growth. *Journal of the European Economic Association*, 37–74.
- Acemoglu, D., Aghion, P., Lelarge, C., Van Reenen, J., and Zilibotti, F. 2008. The Unequal Effects of Liberalization: Evidence from Dismantling the License Raj. *American Economic Review*, **94**, 1397–1412.
- Acemoglu, D., Acikcigit, U., Bloom, N., and Kerr, W. 2013. *Innovation, Reallocation and Growth*. NBER Working Paper 18993.
- Aghion, P., and Howitt, P. 1992. A Model of Growth through Creative Destruction. *Econometrica*, **60**, 323–351.
- Aghion, P., and Howitt, P. 1994. Growth and Unemployment. *Review of Economic Studies*, **61**, 477–494.
- Aghion, P., and Howitt, P. 1998. *Endogenous Growth Theory*. MIT Press.
- Aghion, P., and Howitt, P. 2009. *The Economics of Growth*. MIT Press.
- Aghion, P., and Roulet, A. 2011. *Repenser l'Etat*. Editions du Seuil.
- Aghion, P., and Roulet, A. 2014. *Structural Reforms and Social Mobility*. Mimeo Harvard.
- Aghion, P., Harris, C., and Vickers, J. 1997. Competition and Growth with Step-by-Step Innovation: An Example. *European Economic Review, Papers and Proceedings*, 771–782.
- Aghion, P., Harris, C., Howitt, P., and Vickers, J. 2001. Competition, Imitation and Growth with Step-by-Step Innovation. *Review of Economic Studies*, **68**, 467–492.
- Aghion, P., Bloom, N., Blundell, R., Griffith, R., and Howitt, P. 2005a. Competition and Innovation: An Inverted-U Relationship. *Quarterly Journal of Economics*, **120**, 701–728.
- Aghion, P., Boustan, L., Hoxby, C., and Vandenbussche, J. 2005b. *Exploiting States' Mistakes to Identify the Causal Effects of Higher Education on Growth*. Harvard mimeo.
- Aghion, P., Alesina, A., and Trebbi, F. 2007. *Democracy, Technology, and Growth*. NBER Working Paper No. 13180.
- Aghion, P., Dewatripont, M., and Stein, J. C. 2008. Academic Freedom, Private-Sector Focus, and the Process of Innovation. *RAND Journal of Economics*, **39**, 617–634.
- Aghion, P., Hemous, D., and Kharroubi, E. 2009a. Countercyclical Fiscal Policy, Credit Constraints, and Productivity Growth. *Forthcoming in the Journal of Monetary Economics*.
- Aghion, P., Askenazy, P., Bourles, R., Cetto, G., and Dromel, N. 2009b. Education, Market Rigidities and Growth. *Economics Letters*, **102**, 62–65.

- Aghion, P., Blundell, R., Griffith, R., Howitt, P., and Prantl, S. 2009c. The Effects of Entry on Incumbent Innovation and Productivity. *Review of Economics and Statistics*, **91**, 20–32.
- Aghion, P., Dewatripont, M., Hoxby, C., Mas-Colell, A., and Sapir, A. 2010. The Governance and Performance of Universities: Evidence from Europe and the US. *Economic Policy*, **25**, 7–59.
- Aghion, P., Farhi, E., and Kharroubi, E. 2012. Monetary Policy, Liquidity and Growth. *Harvard mimeo*.
- Aghion, P., Howitt, P., and Prantl, S. 2013. *Patent Rights, Product Market Reforms and Innovation*. NBER Working Paper 18854.
- Aghion, P., Akcigit, U., and Howitt, P. 2014. What Do We Learn from Schumpeterian Growth Theory? In *Handbook of Economic Growth*, 2, Elsevier, pp. 515–563.
- Aghion, P., Dechezlepretre, A., Hemous, D., Martin, R., and Van Reenen, J. 2015a. Carbon Taxes, Path Dependency and Directed Technical Change: Evidence from the Auto Industry. *forthcoming, Journal of Political Economy*.
- Aghion, P., Akcigit, U., Deaton, A., and Roulet, A. 2015b. *Creative Destruction and Subjective Wellbeing*. NBER Working Paper No. 21069.
- Aghion, P., Dewatripont, M., Du, L., Harrison, A., and Legros, P. 2015c. *Industrial Policy and Competition*. Harvard mimeo.
- Aghion, P., Akcigit, U., Bergeaud, A., Blundell, R., and Hemous, D. 2015d. *Innovation and Top Income Inequality*. Harvard mimeo.
- Akcigit, U., and Kerr, W. 2010. *Growth through Heterogeneous Innovations*. NBER Working Paper 16443.
- Akcigit, U., and Kerr, W. 2015. *Growth through Heterogeneous Innovations*. PIER Working Paper 15-020.
- Akcigit, U., Hanley, D., and Serrano-Velarde, N. 2014a. *Back to Basics: Basic Research Spillovers, Innovation Policy and Growth*. NBER Working Paper 19473.
- Akcigit, U., Alp, H., and Peters, M. 2014b. *Lack of Selection and Limits to Delegation: Firm Dynamics in Developing Countries*. Working Paper.
- Bergeaud, A., Cette, G., and Lecat, R. 2014. *Productivity Trends from 1890 to 2012 in Advanced Countries*. Banque de France, Working Paper No. 475, February.
- Bloom, N., Sadun, R., and Van Reenen, J. 2012. Americans Do I.T. Better: US Multinationals and the Productivity Miracle. *American Economic Review*, **102**, 167–201.
- Blundell, R., Griffith, R., and Van Reenen, J. 1995. Dynamic Count Data Models of Technological Innovation. *Economic Journal*, **105**, 333–344.
- Bresnahan, T., and Trajtenberg, M. 1995. General Purpose Technologies: Engines of Growth? *Journal of Econometrics*, **65**, 83–108.
- Byrne, D., Sichel, D., and Oliner, S. 2013. Is the Information Technology Over? *International Productivity Monitor*, **25**, 20–36.
- Cette, G., and Lopez, J. 2012. ICT Demand Behavior: An International Comparison. *Economics of innovation and New Technology, Taylor and Francis Journals*, **21**, 397–410.
- Crisuolo, C., Martin, R., Overman, H., and Van Reenen, J. 2012. *The Causal Effects of Industrial Policy*. CEP Working Paper 1113.
- Dasgupta, P., and David, P. A. 1990. *The New Economics of Science*. High Technology Impact Program Working Paper, Center for Economic Policy Research, Stanford University.

- Dasgupta, P., and David, P. A. 1994. Toward a New Economics of Science. *Policy Research*, **23**, 487–521.
- Dixit, A. K., and Stiglitz, J. E. 1977. Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, **67**, 297–308.
- Foster, L., Haltiwanger, J., and Krizan, C. 2000. Aggregate Productivity Growth: Lessons from Microeconomic Evidence. In: *New Developments in Productivity Analysis*. University of Chicago Press.
- Foster, L., Haltiwanger, J., and Krizan, C. 2006. Market Selection, Reallocation, and Restructuring in the U.S. Retail Trade Sector in the 1990s. *Review of Economics and Statistics*, **88**, 748–758.
- Frankel, J., and Romer, D. 1996. *Trade and Growth: An Empirical Investigation*. NBER Working Paper No. w5476.
- Frankel, M. 1962. The Production Function in Allocation of Growth: A Synthesis. *American Economic Review*, **52**, 995–1022.
- Garcia-Macia, D., Hsieh, C., and Klenow, P. J. 2014. *How Destructive is Innovation?* Working paper.
- Gordon, R. 2012. *Is U.S. Economic Growth Over? Faltering Innovation Confronts the Six Headwinds*. NBER Working Paper 18315.
- Gordon, R. 2013. US Productivity Growth: The Slowdown Has Returned after a Temporary Revival. *International Productivity Monitor*, **25**.
- Haltiwanger, J., Jarmin, R., and Miranda, J. 2010. *Who Creates Jobs? Small vs. Large vs. Young*. NBER Working Paper 16300.
- Hsieh, C., and Klenow, P. 2009. Misallocation and Manufacturing TFP in China and India. *Quarterly Journal of Economics*, **124**, 1403–1448.
- Hsieh, C., and Klenow, P. 2012. *The Life Cycle of Plants in India and Mexico*. NBER Working Paper 18133.
- Hsieh, C., and Klenow, P. J. 2014. The Life Cycle of Plants in India and Mexico. *The Quarterly Journal of Economics*, **129**, 1035–1084.
- Joint Economic Committee (JEC). 2010. *The 2010 Joint Economic Report*. Tech. rept. Washington, DC: Government Printing Office.
- Klette, T., and Kortum, S. 2004. Innovating Firms and Aggregate Innovation. *Journal of Political Economy*, **112**, 986–1018.
- Koch, W. 2014. *Does Financial Structure Matter for Economic Development*. Mimeo UQAM.
- Lentz, R., and Mortensen, D. 2008. An Empirical Model of Growth Through Product Innovation. *Econometrica*, **76**, 1317–1373.
- Mortensen, D., and Pissarides, C. 1998. Technological Progress, Job Creation, and Job Destruction. *Review of Economic Dynamics*, **1**, 733–753.
- Murray, F., Aghion, P., Dewatripont, M., Kolev, J., and Stern, S. 2015. Of Mice and Academics. *American Economic Journal, Micro*, forthcoming.
- Nelson, R. 1959. The Simple Economics of Basic Research. *Journal of Political Economy*, **67**, 297–306.
- Nunn, N., and Trefler, D. 2010. The Structure of Tariffs and Long-Term Growth. *American Economic Journal: Macroeconomics*, **2**, 158–194.
- Romer, P. 1986. Increasing returns and long-run growth. *Journal of Political Economy*, **94**, 1002–1037.
- Romer, P. 1990. Endogenous Technical Change. *Journal of Political Economy*, **98**, 71–102.

- Sampat, B., and Williams, H. 2015. *How Do Patents Affect Follow-on Innovation? Evidence from the Human Genome*. NBER working paper 21666.
- Solow, R. M. 1956. A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, **70**, 65–94.
- Vandenbussche, J., Aghion, P., and Meghir, C. 2006. Growth, Distance to Frontier, and Composition of Human Capital. *Journal of Economic Growth*, **11**, 97–127.
- Williams, H. 2013. Intellectual Property Rights and Innovation: Evidence from the Human Genome. *Journal of Political Economy*.