Innovation Regimes, Job Creative Destruction and the Labour Market

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Abstract

According to mainstream scholars, European employment and productivity faltered because rigid labour markets hinder the adjustment to new ICT technologies. Whereas this view matches the raise of unemployment in low quality jobs, it is not able to explain the differential rates of job creation in high-tech jobs. Alternative approaches extend the institutional domain including product market regulation, adoption costs or educational policies. However, also these approches do not investigate the determinants of job creation and inequality in different part of the job distribution. This paper attempts to address this issue introducing entrant-incumbent heterogeneity in a vintage model with labour market imperfections. Provided that incumbents (entrants) perform incremental (radical) innovations, an innovation regime is endogenous to certain institutional features. We show how this difference might translate into different labour market and productivity outcomes. In periods of faster technical change, countries oriented versus incremental innovations, i.e. Germany, turn out to be disadvantaged w.r.t. countries where entry barriers for innovative firms are lower, i.e. the US. Moreover, we suggest possible ways in which different regulatory reforms end up affecting the job-wage distributions. Finally, we sketch the implications of this approach for productivity growth and show how the endogeneity of entry barriers might hinge upon the shape of the skill distribution.

1 Introduction

It is often argued that European labour markets are the culprit of the sharp increase in unemployment that follows the advent of new ICT technologies. Conversely, flexible Anglo-Saxon institutions allow maintaining a low unemployment rate at the cost of a higher wage inequality, conjuring an inequality-unemployment trade-off (Krugman 1994, Oecd 1994, Ljunqvist and Sargent

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1998, Hornstein et al. 2007). The so-called 'Krugman hypothesis' states that different labour market institutions bring to different social outcomes in response to an acceleration in the arrival rate of new technologies. More recently, to labour market institutions has been also ascribed the differential rate of productivity growth across the two sides of the Atlantic (Gordon and Dew-Becker 2005). Indeed, the employment recovery that followed the 80s downturn has been accompanied by a more pronounced growth of productivity in the US than in Europe (Oecd 2007).

As suggested by empirical analyses (Blau and Kahn 1996, Autor et al. 2005), downward wage rigidities can fairly explain the unemployment-inequality trade-off at the bottom of the employment distribution; however, bringing back to downward wage rigidities the explanation of the differential rates of job creation in high-tech, skill-intensive, industries seems far more problematic (see also European Commission 2001). The counterfactual of Scandinavian economies, characterized by rigid labour markets but sustained rates of technological adoption, contradicts that 'reductionist view' and, at the same time, motivates a closer inspection of other possible sources of divergence. Alternative approaches extend the perimeter of the institutional space by including product market regulation, adoption costs or educational policies in the analysis (Blanchard and Giavazzi 2003, Krueger and Kumar 2004, Amendola and Vona 2008, Duernecker 2008). However, none of these works is able to provide a unified framework to investigate the determinants of job creative destruction in different part of the job distribution and, especially, why the performance of European Economies in high tech sectors deteriorates so much following a phase of faster technological depreciation[1].

In this paper, we share a critical view of the mainstream position by claiming that the complexity of the process of job creative destruction can not be reduced to the outcome of labour market institutions alone[2]. To this end, we build a vintage model with heterogenous firms in order to investigate the determinants of 'job creative destruction' in different parts of the distribution. The vintage structure is a standard tool in the literature (e.g. Hornstein, Krusell and Violante 2007) and it is particularly useful to connect, through scrapping conditions, the process of job destruction to the relation between labour market institutions and capital-embodied technical change. To the best of our knowledge, the idea of considering entrant-incumbent heterogeneity in a vintage model is a new feature of our model, inspired by the Baumol (2001) caveat on the Schumpeter theory. The purpose of the Baumol analysis is to reconcile the apparent conflict between the two Schumpeterian innovation models. Indeed, there exist a division of the innovative labour between incumbents, that perform incremental innovations,

[1] From the empirical side, the acceleration in the rate of capital-embodied technical change has been documented by many empirical papers attempting to measure capital-embodied technical change with the decline in the quality adjusted price index of new goods, for a detailed discussion see Cummins and Violante (2002).

[2] Note that the growing theoretical and empirical literature on endogeous technological adoption (Caballero and Hammour 1998, Acemoglu 2003, Pischke 2004, Koeniger and Leonardi 2006) inverts the relationship between technology and labour markets, but keeps the policy focus only on labour market institutions.

and entrants, that are the vectors of radical innovations. In what follows, we will exploit the idea that different institutional features bring about a different balance between incremental and radical innovations in each country.

The main contribution of the paper is to build a new theoretical framework that is able to stress the endogeneity of an 'innovation regime' (Winter 1984) to entry barriers and to the shape of the skill distribution. In particular, entry barriers are endogenous, depending on the incumbents' learning capacity and on the innovation potential. For a larger innovation potential, entry barriers should decrease so as to accomodate for a decrease in the firms' learning capacity.

We will show that, during periods of faster technological depreciation, an innovation regime that relies more in incremental innovations, and thus in learning, will suffer a more pronounced deterioration of its performance in terms of employment and productivity than an innovation regime oriented towards radical change. Also reforms and institutional adjustments should be substantial in order to reach a new steady state where employment is reabsorbed and the productivity gains are reached. In contrast with the mainstream view, we found that reforms should be focussed in reducing entry barriers for innovative firms, relatively higher in that regime, so as to relocate labour to new, highly productive, plants. Indeed, reducing the union bargaining power or the minimum wage can have a positive effect on employment by making profitable the use of low productive plants, but at not on productivity.

We claim that our approach shed new light on cross country differences in terms of employment and inequality, which appears as the outcome of *chaging* labour market institutions rather than of technological change per sè (Wolff 2006, Lemieux 2006). Moreover, the model is able to provide a theoretical argument to explain why countries with different labour market (Finland and Sweden vs. the US) were able to perform equally well in terms of employment and productivity following the advent of new ICT technology. In particular, in the discussion of the institutional adjustments, we illustrate a possible justification for the observed divergence in unemployment rates among European countries with similar labour market institutions (see also Duernecker 2008). Finally, we construct a variant of the model where the shape of the skill distribution has a paramount impact in explaining different distribution of investment across plants.

The paper is organized as follows. Section 2 illustrates the recent development of debate on the determinants of job creation and earning inequality. Section 3 lays out the general model and presents comparative static results. Section 4 discusses the properties of the equilibrium, lingering on the endogeneity of an innovation system and on the shape of the job distribution. The first part of Section 5 investigates alternative ways in which a system adjusts to an acceleration in the rate of capital-embodied technical change, whereas the second sketches possible extensions of the baseline model. Section 6 concludes.

2 Technology and the Labour Market: Beyond the Krugman Hypothesis

Among the candidate sources of the transatlantic divergence, a growing strand of literature rests upon policy dimensions that sharply differ across the two areas: product market regulation (McKinsey Global Institute 1997, Blanchard and Giavazzi 2003, Ebell and Haefke 2006, Duernecker 2008) and educational systems (Freeman and Schettkat 2003, Krueger and Kumar 2004, Amendola and Vona 2008). Let us review these conditions seriatim.

The literature on product market regulation as a source of unemployment can be conveniently divided into two strands. The first considers a static notion of the distortions associated to regulation and to the lack of competition[3]. Moreover, union bargaining power tends to be jointly associated with product market regulation, hence suggesting reforms aimed at increasing the competitiveness of product markets in order to squeeze the rents due to bilateral oligopoly (Blanchard and Giavazzi 2003). According to Blanchard and Giavazzi, creating the political support for labour market deregulation is difficult if the final market is non-competitive since "labor market deregulation comes with a sharp intertemporal trade-off, lower real wages in the short run in exchange for lower unemployment in the long run" (p. 839). The implication that impediments to free competition tends to jointly emerge in both markets lacks a robust empirical support as long as, for example, Scandinavian economies displays low product market regulation and high labour market protection (Oced 2007). More sophisticated analyses show that the impact of product market reform on employment is marginally higher in systems with more regulated labour market suggesting a substitutability rather than a complementarity relationship between the two policies (Fiori et al. 2007).

A second strand of research emphasizes the negative impact of product market regulation on technological adoption (e.g. Duernecker 2008, see fig. 1). In fact, favorable credit conditions for innovative entrants (Aghion et al. 2009) seems to have a significant impact on job creation, an impact that increases with the arrival rate of novelties. Therefore, the observed difference in the credit conditions for innovative firms between the two sides of the Atlantic can contribute to explain the differentail rate of job creation in high tech firms[4]. With the aim of explaining why unemployment varied across European countries, Duernecker 2008 extends the Hornstein et al 2007 (HKV henceforth) model including differences in adoption costs. In countries where product market regulation is less strict, i.e. Scandinavian and Anglo-Saxon, the upfront cost required to open a

[3] The Oecd 'degree of regulation index' is an average of many variables: barriers to entry, public ownership, price controls, government involvement in business operation, market concentration and vertical integration, tariff and non-tariff barriers. Most of the variables that compose the index reflect a static view of the impact of regulation on job creation.

[4] At the empirical and at the theoretical level it is not clear which form of product market deregulation fosters job creation in high tech jobs. Using a panel of UK firms, Aghion et al. 2009 show that "reducing barriers to entry can magnify the initial differences in incumbent performance" (p.10). This can be a source of dispersion in sector productivities.

new plant is relatively lower offsetting the negative effect on employment of a strict labour market regulation[5]. However, in order to explain the rise of European unemployment as a consequence of an acceleration in the rate of capital embodied technical change, both HKV and Duernecker must assume that, in the initial steady state characterized by similar unemployment rates, the higher structural unemployment in Europe is compensated by a higher frictional unemployment in the US. Therefore, these papers attribute to an unexplained and *ad hoc* factor, namely frictional unemployment, the similar employment and productivity performance of Europe and the US in the pre-ICT era.

The literature that considers differences in educational systems and, more in general, in the skill composition of the workforce also attempts to address the issue of the differential rate of technological adoption. In particular, profound differences in the educational systems can translate via human capital accumulation into differences in terms of unemployment, productivity growth and inequality. In Krueger and Kumar (2004), a country that invests more in specific-skills, i.e. Germany, compared to higher general education, i.e. the U.S., will experience a faster skill obsolescence in periods of intense technical change, due to the emergence of a continuous mismatch in the skill composition of the workforce. That the composition of the expenditures for education can contribute to explain the U.S.-E.U. divergence is confirmed by empirical evidence. Indeed, whereas the figures regarding the educational attainment and the percentage of GDP devoted to tertiary education display a high gap in favour of the U.S., European countries–in particular, Germany–keep investing significantly more than the U.S. in post-secondary vocational education (see table 1).

In a more recent paper, Amendola and Vona (2008) show that higher education policies based on student aids can be more effective in fostering the accumulation of general human capital with respect to a tuition-free university education (see table 2). In countries with rigid labour markets the first policy improves the incentives to attain a degree, whereas in deregulated economies, student aids evenutally offset the emergence of borrowing constraints. In both cases, differences in labour market policies have only a secondary effect on technological adoption and job creation with respect to differences in educational policies. Finally, in an empirical-oriented paper, Freeman and Schettkat (2003) noted that the average skill level, measured by mean of the International Adult Literacy Score of the OECD, is higher in Germany than in the US, and that the variance of the skill distribution is greater in the US with two fat tails around the 25 and 75 percentiles (see figure 2). Per sè lower skill inequality is a source of wage compression, but it can also bring about distortions in the adoption of new technologies since equalizing shooling might prevent the formation of the elite institutions that are the keystone of invention and creative processes (Storesletten and Zilibotti 2000).

Taken together, all these explanations point to profound differences of 'in-

[5] Similar results, although in a general equilibrium model with monopolistic competition, are found by Ebell and Haefke 2006.

novation regimes' between Anglo-Saxons, Scandinavian and Central European Countries. Our claim is that the distribution of investments across plants of different productivity is crucially affected by these 'systemic characteristics' of the innovation regime. A handful point of departure to give a concrete definition to the notion of an 'innovation regime' is the Baumol caveat on Schumpeter innovation models. Baumol (2001) claims that there is no conflict between the view of an heroic inventor/entrepreneur–the so-called Schumpeter I model (1934)–and the one of large oligopolistic firms engaged in routinized R&D–the so-called Schumpeter II model (1942). Incumbents and entrants share the innovative labour according to their specific competitive advantages. In order to remain competitive, incumbents carry on innovative activities aimed at incremental improvements of the existing internal capacity and skills. Entrants, instead, do not bear the burden of destructive innovations on their existing capacity and skills, and moving from a *tabula rasa* can undertake genuine and radical innovative activities. Since small entrants bear a disadvantage in appropriating the returns of R&D activities, innovation is for entrants the only strategy to survive (Klepper 1996). This view is also related to the idea that, during their life-cycle, firms modify the type of innovative activities they carry on (Klepper 1996).

To the scope of our paper, one can advance the hypothesis that not all the innovation systems display the same balance of incremental vs. radical innovation (Winter 1984)[6]. To a certain extent, limited by the ecology of the firms' division of labour (see § 5.3), there are degrees of freedom in the balance between the two activities. In our formalization, the prevalent innovation system endogenously results as the outcome of given institutional features. Entry barriers tend to be higher in countries where institutions supporting incremental innovations and incumbents' learning are stronger. This is because a better learning capacity among incumbents increases productivity and hence reduces the space for entry.

The trade-off between the size of entry barriers and the learning capacity resonates back to the structural factors considered above, such as product market regulation, financial constraint, education and the distribution of skills. During last 30 years the use of new modes of financing innovation–e.g. venture capital–boomed in the US, while credit to innovative entrants is still scarce in continental Europe (Aghion et al. 2009). If entry barriers are not fixed but partially endogenous to the potential of new technologies, this might suggest that the adjustment of entry barriers to faster innovation has been more sticky in systems with higher initial barriers, i.e. Europe. In periods of faster technical change, a low elasticity of entry barriers to innovation induces a sub-optimal entry of new firms and, at the same, reduces employment at the top of the job distribution.

For what concerns education, as Baumol suggested in a recent paper (2004),

[6] According to Winter (1984, p. 297):
"An entrepreneurial regime is one that is favorable to innovative entry and unfavorable to innovative activity by established firms; a routinized regime is one in which the conditions are the other way round". The relative small-firm innovative advantage "is likely to be roughly proportional to the number of people exposed to the knowledge base from which innovative ideas might derive".

the prevalent mode of educating people in Europe spurs the development of a specific and paradigmatic knowledge whereas in the US education offers more opportunities to build creative capacities encouraging the freedom of 'thinking outside the box'. Vocational oriented and dual systems, like the German one, perfectly fit in the paradigmatic mode of teaching. What one would expect is then that the German system is less able to generate radical innovations than the American one. Moreover, in the case of capital-skill complementarity, a more compressed distribution of skills enhances the incentive to invest in middle-skill sectors with respect to high tech sectors that, to exploit their productivity potential, need talents rather than highly specialized workers[7]. All in all, the observed differences in entry barriers, product market regulation and educational system can be seen as interlinked aspects of an 'innovation regime'.

To summarize four assumptions define an innovation regime in our model:

i) Entrants (resp. incumbents) have a comparative advantage in radical (vs. incremental) innovations.

ii) High entry barriers and strict product market regulation deter the entrance of innovative firms. In particular, an inefficient provision of credit to new innovative firms (e.g. lack of venture capital, inefficient technological transfer, etc.) reduce the rate of adoption of radical innovations.

iii) Over time, incumbents accumulate a technological gap with respect to entrants. The capacity of incumbents to fill this gap deteriorates with age due to obsolescence in incumbent capabilities.

iv) An educational system more oriented toward the development of specific skills brings about an innovation regime more oriented toward incremental innovations and, all the same, reinforces incumbent firms.

The next section explicitly formalizes this idea in a model.

3 The Baseline Model

In order to quantify the effect of both an innovation regime and the labour market institutions on job creative destruction, we build a formal model that is able to capture the crucial aspect of the Baumol-Schumpeter model. We consider an economy where different vintages of capital–embodying technologies of different age–coexist with heterogeneous firms. This second source of heterogeneity stems from the different environments faced by entrants and incumbents. The environment is summarized in two dimensions. Firstly, a new plant can incorporate either the leading edge or an 'updated technology' depending on the type of firm that carries on innovation. Entrants have a comparative advantage in adopting radical innovations that are exogenous, while incumbents *choose* the size of the

[7] The paper of Koeniger and Leonardi 2006 provides empirical evidence that the distribution of investments is less dispersed in Germany than in the US.

innovative efforts. To capture the notion of firm life-cycle, the learning capacity of incumbents depreciate over time[8].

Secondly, as in vintage models, firms support a sunk cost to open a new plant which–due to reputation effect or more valuable collateral–is higher for entrants than for incumbents. This captures the degree of entry barriers in our model. The optimal lifetime of both firms and plants is endogenized: firms remain in the market until their advantage due to lower investment costs is more than offset by a depreciation of its learning capacity; plants are scrapped when profits go to zero. Similarly to HKV 2007 and Moene and Wallerstein 1997 (MW), the latter condition crucially depends on labour market institutions that are captured here by a minimum wage and a Nash-bargaining rent.

3.1 Production

Following HKV 2007 and MW 1997, we assume that each plant employs a worker. We consider the following variant of the production function used in HKV 2007:

$$y(t,a) = k_0 e^{\delta t - g(\delta) a} \tag{1}$$

where δ is the rate of capital-embodied technical change, a is the age of the plant, and $g(.)$ with $g'(.) > 0$ and $g''(.) \leq 0$ is a function that reduces the sensitivity of the scrapping time to the rate of capital embodied technical change (see next section). To prove the main results, we will assume–without loss of generality–a linear technological depreciation: $g(\delta) = \delta$. However, in the analysis of the adjustment process (see §5.1), we consider a concave function $g(\delta) = \delta^{\nu}$ with $\nu < 1$.

We normalize the output of a plant using the leading edge technology to 1. Since we focus on steady states and, for simplicity, we are assuming that the only source of growth is capital-embodied technical change, normalization[9] consists in dividing each variable by $e^{\delta t}$. The normalized production function becomes:

$$y(a) = e^{-g(\delta) \cdot a} \tag{1.bis}$$

Therefore, through the paper all variables are divided by $e^{\delta t}$.

[8] Note that here for sake of simplicity we model learning sequentially, that is: we assume that an incumbent firm does not start investing in the updated technology before the old process comes to an end. Learning however occur at given intervals only in steady state and there is no reason to guess that in any steady states learning should occur at irregular intervals. Instead, an acceleration in the rate of technical change that brings the system far from its steady state path increases the frequency of the learning. This is due to the vintage structure of capital: an acceleration in the rate of technical change induces a faster scrapping of old plants and thus a more frequent learning.

[9] In the appendix B.3, we provide further details on the assumptions required to normalize the main economic variables.

3.2 The Entrant Problem

The entrant problem is standard; we lay out it in order to remind the vintage capital approach. The expected value of a new plant embodying the leading edge technology is:

$$V_0 = \int_0^{\overline{a}_0} e^{-(r-\delta)a}\pi(a)da \tag{2}$$

where $\pi(a) = q(a) - w(a)$. The discount factor r is adjusted for the rate of embodied technical change δ[10]. A plant remains open until the stream of instantaneous profits goes to zero. The optimal lifetime of a plant $\overline{a}_0$ is therefore the solution of the equation: $\pi(\overline{a}_0) = 0$. The optimal scrapping age $\overline{a}_0$ essentially depends on the way in which the wage is determined. As usual in the literature (e.g. Acemoglu 2003), the wage is equal to a share α of productivity if the minimum wage is not binding; otherwise, it is equal to the minimum wage $\underline{w}$:

$$w(a) = \max[\alpha q(a), \underline{w}] \tag{3}$$

where $q(a) = e^{-\delta a}$ is the productivity of the plant a. This function nests both the case of a purely centralized bargaining where $\alpha = 0$ and $\underline{w}$ is proportional to the average productivity across plants, i.e. $\underline{w} \in (0, 1)$, or 'intermediate cases' where a certain degree of wage regulation–i.e. a wage floor–coexists with a local bargaining at the plant level. Imposing that $\underline{w} < 1$, we are able to make explicit the scrapping condition $\pi(\overline{a}_0) = 0$:

$$\overline{a}_0 = \frac{1}{\delta}\log\left(\frac{1}{\underline{w}}\right) \tag{4}$$

A closer inspection of equation [4] shows that the classical trade-off between employment, on the one hand, and labour market regulation, on the other, holds. In particular, differentiating [4] with respect to $\underline{w}$, we get that a higher wage floor reduces the optimal lifetime of a plant, $\frac{d\overline{a}_0}{d\underline{w}} < 0$, and increases unemployment as older plants are scrapped earlier. Finally, an acceleration in the rate of technical change makes new plants relatively more profitable with respect to old plants and hence reduces the lifetime of an old plant, $\frac{d\overline{a}_0}{d\delta} < 0$. The magnitude of $\frac{d\overline{a}_0}{d\delta} < 0$, i.e. the impact of technical change on firm lifetime, is very large since δ belongs to the interval between $(0.02, 0.08)$. Therefore, in numerical analyses, the effect of δ on employment tends to be paramount w.r.t. the effect of other relevant variables. In contrast, the assumption that technological depreciation is non-linear in the rate of capital embodied technical change allows evaluating in a more realistic set-up the effect of an acceleration in the rate of capital-embodied technical change on employment and productivity (see § 5.1).

The size of the Nash share α does not affect the scrapping age, but does determine the age until which the bargained wage is paid. More precisely, there

[10] Notice that eq. [1] implictly captures the comparison between the value of an old and the one of a new plant because the output is normalized to the one of the leading-edge technology and the discount factor is adjusted for the expected rate of technical change.

will exist a a_0^+ such that $\alpha \cdot q(a) = \underline{w}$ then from $a \in (a_0^+, \overline{a}_0)$ workers get $\underline{w}$ where:

$$a_0^+ = \frac{1}{\delta} \log \left(\frac{\alpha}{\underline{w}} \right) \tag{5}$$

and $\overline{a}_0 > a_0^+$ if $\alpha < 1$, a condition that is always verified. The higher is α, the smaller is the share of workers that are paid the minimum wage. Obviously, everybody is paid the same wage $\underline{w}$ if $\underline{w} > \alpha$. This case can be seen as the centralized case in our model.

Taking into account a_0^+, the value of the plant becomes:

$$V_0 = \int_0^{a_0^+} e^{-(r-\delta)a} \left[(1-\alpha) e^{-\delta a} \right] da + \int_{a_0^+}^{\overline{a}_0} e^{-(r-\delta)a} \left[e^{-\delta a} - \underline{w} \right] da \tag{1bis}$$

The 'free entry' condition allows to determine the size of investments made by entrants. If the unitary cost of a new plant is growing with the number of plants opened and is proportional to $\overline{c}_0$, entrants invest up to the point the up-front cost of a new plant $C_0(n)$–with $C_0'(n) > 0$–equal its expected value:

$$C_0(n_0) = V_0 \tag{6}$$

Recall that n_0 is also the number of workers employed in a new plant. For sake of simplicity let us start with a simple linear cost function[11]:

$$\overline{c}_0 n_0 = V_0 \tag{7}$$

$\overline{c}_0$ is the cost of a new plant for an entrant. The assumption of an up-front cost that increases with the size of investments is not warranted empirically but it is required in these models to determine the optimal investment size (MW 1997). Let us now analyse the incumbent problem.

3.3 The Incumbent Problem

Incumbents enjoy an advantage in terms of lower investment costs. Many factors may affect the size of the incumbents vs. entrants cost gap $\overline{c}_0 - \underline{c}_i$: lower credit costs due, for example, to higher reputation or to project co-financing[12]; product market regulation or cheaper complementary factors (licences, specific skills, etc). In turn, incumbents suffer a technological gap vis à vis to entrants and thus carries on incremental innovations. To keep things as simple as possible, we assume that–upon an investment in innovation–a firm successfully obtains an improvement of a given size λ with a probability $p_\delta^i(\chi)$ depending on the

[11] In the appendix B.1, we prove the main result for a more general cost function concave in n: $c(n) = c_0 n^\alpha$, $\alpha < 1$

[12] Here co-financing is possible because firms are left with profits Π_1 after the first production round. In particular: $\Pi_1 = \int_0^{\overline{a}_0} \pi(a)da > V_0 - \overline{c}_0 n_0$. This means that they can share the investment costs with the bank.

effort χ and on the technological parameters (rate of technical change δ, firm age i). Else, the firm has free access to a 'backstop technology' that is distant i to the leading-edge. The value of a plant in the bad case is:

$$\underline{V}_i(V_0) = \int_0^{a_i^+} (1-\alpha) \cdot e^{-(ra+i\delta)} da + \int_{a_i^+}^{\overline{a}_i} e^{-(r-\delta)a} \left[e^{-(\delta a + i\delta)} - \underline{w}_i \right] da \tag{8}$$

with a_i^+ s.t. $\alpha \cdot q(a) = \underline{w}_i$ so $a_i^+ = \frac{1}{\delta}\log(\frac{\alpha}{\underline{w}_i}) - i$ and $\overline{a}_i$ s.t. $\pi(\overline{a}_i) = 0 \rightarrow \overline{a}_i = \frac{1}{\delta}\log(\frac{1}{\underline{w}_i}) - i$

We can make two assumptions about the wage floor $\underline{w}_i$, namely that there is a 'sector specific' wage floor, i.e. $\underline{w}_i = e^{-i\delta} \cdot \underline{w}$, or that the wage floor is unique in all the economy so, after the normalization, we get: $\underline{w}_i = \underline{w}$.

In sum, the incumbent i decides to invest in incremental innovations χ and get:

$$\begin{array}{l} \overline{V}_i(V_0) \text{ with probability } p_\delta^i(\chi) \\ \underline{V}_i(V_0) \text{ with probability } 1 - p_\delta^i(\chi) \end{array}$$

where

$$\overline{V}_i(V_0) = \int_0^{a_i^+} (1-\alpha) \cdot \lambda e^{-(ra+i\delta)} da + \int_{a_i^+}^{\overline{a}_i} e^{-(r-\delta)a} \left[\lambda e^{-(\delta a + i\delta)} - \underline{w}_i \right] da \tag{9}$$

where $\lambda > 1$ is a proxy for the learning capacity. The two critical age are: a_i^+ s.t. $\alpha\lambda \cdot q(a) = \underline{w}_i$ so $a_i^+ = \frac{1}{\delta}\log(\frac{\alpha\lambda}{\underline{w}_i}) - i$ and $\overline{a}_i$ s.t. $\pi(\overline{a}_i) = 0 \rightarrow \overline{a}_i = \frac{1}{\delta}\log(\frac{\lambda}{\underline{w}_i}) - i$. Obviously, a firm that succeeds in innovation scraps the plant later: $\overline{a}_i(\lambda) > \overline{a}_i$. The probability of success linearly depends on the effort χ, is decreasing in the firm age and is exponentially decreasing in the rate of technical change.

$$p_\delta^i(\chi) = \frac{\chi}{i \cdot e^{\xi\delta}} \tag{10}$$

With $\xi > 1$,capturing the speed of depreciation in the incumbent innovative capacity. Incumbent i invest up to the point where the cost equals the value of the plant:

$$n_i \cdot (\underline{c} + c(\chi)) = p_\delta^i(\chi) \cdot \overline{V}_i(V_0) + (1 - p_\delta^i(\chi)) \cdot \underline{V}_i(V_0) \tag{11}$$

Where $c(\chi)$ is the cost of the innovative effort χ[13]. In particular, χ_i is determined in order to maximize the investment n_i : $\max_\chi [n_i]$ with $\chi < ie^{\xi\delta}$.

[13] An interesting implication of our model is that condition [11] is not a free entry condition but simply maintain that existing firms invest up to the point where costs and benefits equalize. If seen in a whole macroeconomic framework, the relevant constraint for incumbent firms is the size of the market as in the microeconomic textbooks of imperfect competition. Thus incumbents decide how much to invest according to demand expectations $\widetilde{d}_i$: $n_i = \min\left\{\widetilde{d}_i,\ n_i^*\right\}$ where n_i^* solves $\max_{\chi_i}\{n_i\}$. Obviously, if prices are given, Cournot competition would imply that incumbents equally share the market.

Note that the competition among incumbents push investments up to the point where the cost of a plant equals its value.

We are now able to establish an important result:

Proposition 1 *The innovative effort* χ *is greater than zero iff* $n_{\{\chi>0\}} > n_{\{\chi=0\}}$ *and the optimal investment in incremental innovations* χ_i^* *is the implicit solution of the equation:*

$$n_i = \frac{p_\delta^i(\chi)\left(\overline{V}_i(V_0) - \underline{V}_i(V_0)\right) + \underline{V}_i(V_0)}{c(\chi) + \underline{c}} \tag{12}$$

Moreover (proofs in the appendix B.2):

i) *A necessary and sufficient condition for the existence of an interior solution in the meaningful range of the parameters is that* $c(\chi)$ *is convex in* χ*. Moreover,* $\overline{\chi}_i = \left\{\frac{\underline{c}}{c_t} \cdot \frac{1}{i \cdot e^{\xi\delta}} \cdot \left[\frac{\overline{V}_i - \underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$ *is the locus of point for which* $n_{\{\chi>0\}} = n_{\{\chi=0\}}$ *(see also fig. 3).*

ii) *The sequence* $\{\chi_i^*\}_{i\in\mathbb{N}^+}$ *is monotonically decreasing.*

iii) $\exists\ k < \infty : \chi_k = \varepsilon$ *with* ε *close to* 0*. Incumbents remain in the market up to the point where their comparative advantage fades away. Thus, k is the optimal firm lifetime.*

iv) $\partial k(\lambda)/\partial\lambda < 0$, *a better learning capacity* <> *longer firm lifetime.*

It is appropriate at this point to establish some comparative static results (proofs in the appendix B.2).

Proposition 2 *The optimal learning effort* χ_i^* *is increasing in the learning capacity:* $\partial\chi_i^*/\partial\lambda > 0$*.*

Proposition 3 *If certain conditions are satisfied, the learning effort tends to increase with the rate of technical change.*

Proposition 4 *The sharper the distance between successive technologies (a higher* δ*), the lower the effectiveness of the learning effort. Moreover, incumbents' investments tends to decrease with respect to entrants:* $\frac{dn_i}{d\delta} < \frac{dn_0}{d\delta}$*.*

The first proposition is obvious: higher potential gains from incremental innovations bring about larger innovative efforts by incumbents. The second proposition states that incumbents might increase their efforts in periods of faster technical change to reduce the distance from the leading-edge technology and is coherent with the empirical evidence (Aghion et al. 2009). The third is essential to our argument: in phases of intense technical change, the technological environment deteriorates for incumbents and their investments decline, thereby employment tends to decrease relatively more in an innovation regime more oriented towards learning.

The optimal firm lifetime allows to identify the equilibrium flow of entry and exit. Let us turn to the analysis of the equilibrium.

4 Equilibrium and Aggregate Characteristics of the System

In equilibrium we should have that entry equals exit: $n_0 = n_k$ or that:

$$\frac{\overline{c}}{\underline{c}} = \frac{V_0}{\underline{V}_k} \tag{13}$$

Proposition 5 *In equilibrium an 'innovation regime' displays a trade-off between learning capacity λ and entry barriers: a larger k due to a better learning capacity implies the lower $\underline{V}_k$ and a higher equilibrium level of entry barriers $(\frac{\overline{c}}{\underline{c}})^*$. The opposite occurs for a low k.*

Proof. From the previous analysis: $\partial \underline{V}_k / \partial k < 0$ so if k is larger, the equilibrium level of entry barriers $\frac{\overline{c}}{\underline{c}}$ should be lower to ensure a balanced flow of entry and exit. ■

The interesting implication of this proposition is that entry barriers are endogenous to the learning capacity of the system. For a given rate of technical change, the intuition is that–in systems where incumbents are more efficient–the space for entrants is smaller. This result is our point of departure to compare systems more oriented towards radical innovation (with low entry barriers and high learning) with a system more oriented towards incremental innovation.

A important caveat is worthy to be stressed at this point. Proposition [5] establishes a substitutability between radical and incremental innovations that is justified by the idea that incumbents appropriate a greater fraction of innovative rents in system with higher entry barriers. However, positive spillovers from radical to incremental innovations are also present as long as radical innovations improve the whole innovation potential. This is especially true when a technological revolution widens the scope for path-breaking changes in the productive capacity. The next proposition clarifies this point, while, in § 5.3, we partially relax the substitutability assumption accounting for spillover from entrants to incumbents.

Proposition 6 *The level of barriers that ensures zero net entries is related to the rate of technological obsolescence. The higher is δ, the lower should be the entry barriers.*

Proof. Differentiating $\frac{V_0}{\underline{V}_k}$ with respect to δ, it easy to get: $\frac{\partial}{\partial \delta}\left(\frac{V_0}{\underline{V}_k}\right) > 0$. ■

In correspondence to a faster technological obsolescence, the profitability of investing for incumbent of age k with respect to entrants widens due to the joint effect of a higher distance among successive technologies and of a lower effectiveness of learning. To fix this result, in figure 5, we plot the ratio $\frac{\underline{V}_k}{V_0}$ against δ in correspondence to random samples of the other relevant parameters.

The learning parameter λ is critical to identify the equilibrium pattern of firms' investments during their life-cycle. Three cases deserve to be considered:

1. If the potential gains from incremental innovation are very low, firms exit the market after 1 period as the lower investment cost is not enough to compensate for the worse technological environment faced by the incumbent. $\lambda_1 \simeq 1 : \chi_1 = \varepsilon$, and the equilibrium level of entry barriers is very small $\left(\frac{\overline{c}}{\underline{c}}\right)^* = \frac{V_0}{\underline{V}_1} = e^{\delta}$.

2. In the second extreme case, if λ is such that $V_0 < V_1$, 'technological leapfrogging' occurs and–since also institutional conditions favour incumbents– the increase of investments from 0 to 1 is very large.

3. Within the range of $\lambda \in (1, \lambda_2)$ where λ_2 is the leapfrogging level of λ, the sequence of investments by firms of different age increases from 0 to 1 because the lower investment cost more than compensate the worsening of the technological conditions, $V_0 > V_1$. From age 2 on, investment starts decreasing up to the point where the comparative advantage of incumbents fades away (i.e. for $i = k$).

Next section discusses how differences in innovation regimes and labour market institutions affect the characteristics of the equilibrium level of the main economic aggregates.

4.1 Aggregate Characteristics of the System

Aggregate employment L is the sum of employment across firms and reads:

$$L = \sum_{i=0}^{k}(1 - p_i^{\delta}) \cdot \overline{a}_i \cdot n_i + \sum_{i=0}^{k} p_i^{\delta} \cdot \overline{a}_i(\lambda) \cdot n_i \leq N \tag{14}$$

where clearly $p_0^{\delta} = 1$ and $\overline{a}_i(\lambda) = \overline{a}_0$. N is the active population.

Due to earlier scrapping, aggregate employment tends to decrease the more regulated the labour market. On the other side, however, employment increases with the learning capacity–$\partial\overline{a}_i(\lambda)/\partial\lambda > 0$ and $\partial n_i(\lambda)/\partial\lambda > 0$. The equilibrium level of unemployment is:

$$U = \min(N - L, 0) \tag{15}$$

with $\frac{\partial U}{\partial \lambda} < 0$ and $\frac{\partial U}{\partial \underline{w}} > 0$. Therefore, a system with rigid labour market institutions can offset the negative effect on employment enhancing the system's learning capacity through policies that favour the worker relocation from old to new plants such as retraining or direct interventions in the educational stream. In Vona and Zamparelli 2009, for instance, we showed that the appropriate relocational policy depends on the characteristics and the type of the process of technical change.

In order to compute the aggregate level of output, we need to consider not only the heterogeneity in firms' age but also the one in plant quality. More precisely:

$$Y = y_0 + \sum_{i=1}^{k} \left[(1 - p_i^{\delta}) \cdot y_i \right] + \sum_{i=1}^{k} \left[p_i^{\delta} \cdot y_i(\lambda) \right] \tag{16}$$

where $y_i = n_i \cdot \left\{ \int_0^{\overline{a}_i} q(a) \cdot da \right\}$ and $y_i(\lambda) = n_i \cdot \left\{ \int_0^{\overline{a}_i(\lambda)} \lambda q(a) \cdot da \right\}$

In our model, a given level of aggregate employment and output is compatible with various configurations of the institutional parameters. This is a desiderable feature of the model as it does not have to resort to *ad hoc* mechanisms in order to explain why, for instance, systems with different labour market institutions might display similar unemployment rates in periods of slow technical change[14].

Notice that the independence of the investment of firm i–i.e. n_i–from plant quality a holds only in steady state. In contrast, during the transition from an economy with a rate of technological depreciation δ to an economy with a rate δ', a non-uniform and lumpy adjustment of investment of different firms in different plants occurs. In this case, the two sources of heterogeneity interact in the determination of the total output: $y_i = \left\{ \int_0^{\overline{a}_i} n_i(a) q(a) \cdot da \right\}$[15].

Using previous results, the aggregate labour productivity reads:

$$Q = \sum_{i=0}^{k} \frac{\overline{a}_i n_i}{L} \left\{ (1 - p_i^{\delta}) \cdot y_i + p_i^{\delta} \cdot y_i(\lambda) \right\} \tag{17}$$

In line with the empirical evidence (Oecd 2007), the aggregate productivity is positively correlated with unemployment since an early scrapping has a negative impact on employment and, at the same time, selects out low productivity plants.

The joint effect on economic aggregates of learning, entry barriers and labour market institutions is difficult to quantify without resorting to numerical analysis. Numerical analyses show that, for instance, the negative effect on employment of an increase by 10% of the wage floor $\underline{w}$ is compensated by a 0.9% improvement in the learning efficiency. More in general, whereas it is impossible to identify a continuum of values of λ that keeps aggregate variables unchanged for different value of $\underline{w}$[16], systems with better learning can support higher wage floor without consequence on aggregate employment. Moreover, better learning compensates for higher wage floors but its effect is lower the faster technological depreciation. Using the previous example as a benchmark and considering a

[14] The main *ad hoc* assumption of the literature on the transatlantic divergence (e.g. Hornstein et al 2007) is that frictional unemployment is higher in the US (while structural unemployment is higher in Europe, due to rigid LMI). Therefore, an acceleration in the rate of capital embodied technical change increases structural unemployment in Europe with respect to the US.

[15] Moreover–as we will discuss later–if also the institutional charateristics of the system are affected by the disequilibria created during the transition process (for example, if the wage floor declines with unemployment), technological decisions of firms are made in a changing institutional environment and hence a further degree of complexity adjoins to the model.

[16] The effect of learning is non-linear due to the jumps in the optimal firm lifetime

rate of capital embodied technical change of 1% higher, λ should now increase by 4.1% in order to keep unemployment and output unchanged in a system with a wage floor of 10% higher.

Critical to our analysis is to assess the impact of an acceleration in the rate of capital-embodied technical change in countries with different innovation regimes. Comparative statics excercises, made through numerical analyses, confirm that, all the same, the employment performance deteriorates significantly more in systems where the incremental-mode of innovation is preminent (fig. 6,7,8). In correspondence to a permanent technological shock of 0.003, a system with a learning capacity higher by 0.3 ends up with an additional 3% in the unemployment rate. The effect is highly non-linear due to jump in the optimal firms lifetime. In particular, discontinuities in the relationship $dL(\lambda)/d\delta$ occur as a consequence of an increase in the optimal firm lifetime, which is in turn driven by the positive relationship between incremental and radical innovations, i.e. $\frac{\partial \chi^*}{\partial \delta} > 0$. This is exactly what proposition 5 stated: the capacity of doing incremental innovations deteriorates with the technological distance δ, hence a system more oriented towards that type of innovation tends to support a larger employment decrease.

Even more interesting, the worsening in the employment performance tends to be accompanied by a parallel decrease in aggregate productivity. In particular, an innovation regime more oriented on incremental innovation fails to obtain the productivity gains related to an acceleration in the rate of capital-embodied technological change. Figures 9-10 display the effect on productivity growth of small and large increases in the rate of capital-embodied technical change. Notably, both for small and large permanent technological shocks, a system with low entry barriers is able to convert into effective productivity gains a larger fraction of the augmented technological potential. On the other hand, our numerical excercises show that an innovation regime based on incremental innovation is more sticky to adapt to novelties: following an acceleration in the arrival rate of novelties, the growth rate of productivity declines because a longer firm lifetime increases the mass of low productivity plants. Therefore, differences in innovation regimes might represent a reliable explanation of the joint long-run decreases of employment and of productivity growth experienced by many European countries in last thirty years.

It is worthy to stress that–by (non-linearly) increasing the optimal lifetime of the marginal firm k–a greater learning effort has also an impact in the wage-productivity distribution. A closer inspection of the equilibrium distributions of productivity and employment consents to illustrate this effect.

4.2 Equilibrium Distributions of Employment and Wages

Figure 5 depicts the employment density in correspondence to different values of the learning parameter. Systems with better learning displays a more dispersed distribution of employment across firms due to a longer firm lifetime.

However, a relatively dispersed employment density might correspond to a relatively compressed wage and productivity density. The reason is that scrapping time is decreasing in age; thus, older incumbents should invest more often in order to overcome their technological disadvantage and, to this purpose, shut low productive plants. In other words, the varieties of plant qualities in use decreases with firm age.

Table 3 helps in clarifying this point. In steady state, firms of age 0 are distributed uniformly in the interval $(0, n_0)$; firms of age 1 are distributed uniformly in the interval $(0, \overline{a}_1^e)$ where $\overline{a}_1^e$ is the average scrapping age of firms at age 1–a linear combination of the scrapping age of firms of age 1 that succeed in incremental innovations and of those that fail. Now, since $\{\chi_i^*\}_{i\in\mathbb{N}^+}$ is monotonically decreasing also the sequence $\{\overline{a}_i^e\}$ is monotonically decreasing, therefore technological variety narrows as the firm becomes older.

More formally put, the wage-productivity dispersion is the sum of the wage dispersion of firms of different ages. Since plants are distributed uniformly within firm ages, we easily get:

$$Var(w) = \sum_{i=1}^{k} \phi_i \cdot Var(w_i) \tag{18}$$

where ϕ_i is the employment density. For a uniform distribution in the interval $[\min(w_i), \max(w_i)]$ the variance is increasing in the length of the interval: $Var(w_i) = \left(\frac{\max(w_i)-\min(w_i)}{12}\right)^2$. Let us distinguish two cases. First, if the wage floors are determined locally, both $\min(w_i) = \underline{w}_i$ and $\max(w_i) = \alpha\lambda \cdot (q(0)/e^{i\delta})$ are decreasing in i. So, the effect on inequality of a longer firm lifetime mainly depends on the compositional effect, i.e. the effect on the shares ϕ_i. A higher share of old firm paying relatively low wages tends to decompressed the bottom part of the wage distribution. In other words, an increase in the optimal firm lifetime increases the mass of employment in less productive plants that pay lower and lower minimum wages, hence increasing the wage dispersion in the bottom tail. In turn, this increase of the bottom tail wage inequality drags along a higher overall level of wage dispersion. In the alternative case where the minimum wage is unique, i.e. $\min(w_i) = \underline{w}$, the length of the interval $[\min(w_i), \max(w_i)]$ is decreasing for $i > 1$. As a result, inequality should decrease the longer the firm lifetime. Comparative statics excercises, made with computer simulations, confirm these results (see table 4-5).

We resort to numerical exercises also to quantify the joint impact of learning and labour market characteristics on wage inequality. This excercise shows that higher wage floors, associated to a more regulated labour market, produces an effect of the 'first order' on wage compression both at the bottom and at the top of the distribution. Moreover, independently from the bargaining system, the effect of faster technological change on the income distribution is only of the 'second order'. The reason is that more sustained technological obsolescence induces an earlier scrapping of less productive plants and therefore have a prominent impact on 'job destruction', not on inequality. In the case of a unique wage floor–where 'job destruction' is more pronounced–inequality decreases; the opposite occurs in the case of firm-specific wage floors since the sharper technological gap is directly mapped into the wage distribution. This suggests that only if bargaining mechanisms adjust enough to reabsorb labour market disequilibria, overall inequality eventually raises (see next section). This is consistent with empirical analyses that attribute to *changing* labour market institutions such as decreases in the minimum wage or deunionization a prominent role in explaining the inequality trends in the U.S. (e.g. Lemieux 2006, Wolff 2006).

Secondly, a bargaining system characterized by a relatively high nash share and a relatively low wage floors tends to generate a much higher wage dispersion, both at the bottom and at the top of the distribution. This confirms recent empirical investigations emphasizing the large impact on inequality of the diffusion of performance-related schemes and, more in general, decentralized forms of bargaining (Oecd 2004, Lemieux 2006).

Next section briefly discusses possible adjustment mechanisms to an acceleration in the rate of capital-embodied technical change. Thereafter, we present some extensions of the baseline model.

5 Extensions of the Baseline Model

5.1 Equilibrium Institutional Adjustments: a discussion

The analysis of the dynamics of job creation and wage inequality through numerical comparative statics allows to assess how different institutional features consent to absorb an acceleration in the rate of technological depreciation. However, this effect can not be measured in *vacuum* as long as a permanent modification in the technological fundamentals induces changes in behaviours that are translated into changes of the institutional features.

The standard way to study adjustements in the mainstream literature is to trace the path followed by the main economic variables as if rationl agents continuously update their plans. Differently from the mainstream approach, in this paper, adjustment occurs along the institutional domain. Adjustment mechanisms are thus not the outcome of microfounded agent's behaviours but follows patterns that depends on imperfect and sticky institutional behaviours. To keep thinks simple, in this first work, adjustment means a comparison of an initial steady state with certain characteristics with a final steady state where some institutions changed[17].

In what follows, in order to make scrapping less sensible to technological depreciation, we will use the more general production function: $y(a) = e^{-g(\delta)\cdot a}$ where the effective technological depreciation is $g(\delta)$. We will consider the effect of downward wage flexibility on employment and productivity, and its

[17] The ideal set-up to analyse this kind of adjustments would be an out-of-equilibrium one where the use of open loop simulations overcome the lack of analytical tractability in the analysis of the technological transitions. Here, however, there is no potential source of multiple outcome but the institutional adjustment per sè. Path dependence processes due, for example, to self-fulfilling expectations or to the interactions of disequilibria in different markets, are ruled out by assumption in our 'supply-side' model.

interaction with, respectively, a decrease in investment costs[18], deunionization and decentralization in the bargaining.

The main result of this preliminary excercise is that–in all the cases considered (unique wage floor or not, different innovation regimes)–an economy that relies only on downward wage flexibility to restore the initial level of employment would reach a final steady state characterized by a substantially increased wage inequality and a sharp decline in productivity, brought about by labour relocation towards low quality plants (tab. 6-9, row 1). Indeed, the wage floor cut is accompanied by an increase in the optimal plant lifetime of 10% on average, a figure that does not match the observed decrease in the lifetime of capital in the US in last 30 years (HKV 2007). Coherently with the argument that in systems more oriented towards incremental innovations the adjustment is more difficult (tab.7-9, r.2), the wage floor should decrease more in order to reduce employment at the pre-shock level. If one consider changes in the whole bargaining system, i.e. decentralization and deunionization, the additional effect is an increase in inequality which is particularly sharp in the case of reforms promoting decentralization (lower $\underline{w}$ and higher α), both in the case of a unique wage floor and in the one of specific wage floors(tab.6-9,r.3)[19]. Conversely, the joint effect of deunionization and of a decrease in the wage floor is to enhance wage inequality at the top of the distribution, especially in systems with a unique wage floor. This effect is a consequence of the fact that a lower α reduces the fraction of people who receive the productivity related wage $\alpha q(a)$ and this tends to widen the gap between the top 90 percent of the distribution and the median (tab.6-9,r.4).

More important, a decrease in investment costs when accompanied by a slight cut in the wage floor allows to accomplish the passage to a new steady state with a level of productivity ranging between 4% and 9% above the initial one. This suggests that the capacity of countries as the US, Finland, Sweden and Australia of escaping the productivity-employment trade-off (Oecd 2007), and so to expand employment not at the cost of a lower productivity, might be seen as the consequence of an innovation regimes more oriented towards novelties, i.e. able to foster job creation in high tech firms. Moreover, this result contributes to the debate on the unemployment divergence across European economies which is mainly related to the degree of deregulation and entry barriers in the final market.

In the case of joint and mild reforms both in the final and in the product market, the job creation effect is remarkably in favour of new plants. On the one hand, if full employment is ensured through a decrease in the wage floor (tab.6-9, r.1), the relocation of labour towards low tech plants, is such that the entrant share of employment ϕ_0 decrease by around 9%. On the other hand, if mild reforms both in the final and in the labour are carried on (tab.6-9, r.5), the share

[18] Since we are comparing two steady states, the equilibrium condition $\frac{\overline{c}}{\underline{c}} = \frac{V_0}{\underline{V}_k}$ must hold. So a decrease in the investment costs should be common to entrants and incumbents. However, as the ratio $\frac{V_0}{\underline{V}_k}$ decrease with δ, this policy tends to favour mainly new entrants.

[19] This is because the higher α, the smaller the share of workers paid the minimum wage

of labour in new innovative firms decrease by an impressive 61%. More in general it is possible to show that the entrant share of employment is increasing in the investment costs. When one compares countries with different institutional features, again innovation regimes initially more oriented towards incremental innovation (EU-type, tab. 7-9, r.5) requires sharper institutional changes to adapt. Finally, full employment is guaranteed in the new steady state at a decreasing level of inequality when a slight degree of deunionization accompany the decrease of the investment costs. This effect occurs because deunionization decreases the fraction of individuals that are paid at the bargainig wage, hence pushing a greater fraction of workers towards the (unchanged) wage floor (tab. 6-9, r.6).

A final remark deserves to be stressed. In our model, entry barriers are endogenous and depend on the learning capacity λ, therefore in comparing two steady states we can not study the outcome of reforms aimed at reducing the entry cost only for innovative entrants (i.e. venture capital). In future extensions we will investigate this case by expliciting the behaviour of the financial sector in the allocation of funds between incuments and entrants.

Next two sections sketch possible extensions of the model.

5.2 Skill Distribution and Investment Behaviours

In this section, we extend the model by including heterogeneous labour in order to connect the endogeneity of investment behaviours to educational policies through the shape of the skill distribution. We will show that, given the level of entry barriers, the skill dispersion has a paramount impact on the distribution of investments across plants. The empirical evidence in favour of a more dispersed skill distribution in the US than in Germany has been documented by Freeman and Schettkat (2003). What we claim here is that a country with a skill distribution characterized by a large cohort of highly skilled people adapts better to an acceleration in the rate of technical change than a country with a distribution of skill relatively more compressed.

To see this, consider the case where plant productivity depends on the worker's skill. In order to capture capital-skill complementarity in a parsimonious way and consistently with a large empirical evidence (e.g. Bartel and Sicherman 1987), we further assume that the effect of skill on plant productivity fades away older plants:

$$y(a) = \begin{cases} h \cdot q(a) & \text{if } \ a < \underline{a} \\ q(a) & \text{if } \ a \geq \underline{a} \end{cases} \tag{19}$$

Therefore, the skill distribution $h \in \left[1, \overline{h}\right]$ displays a mass point of density $\psi \in (0,1)$ for $h = 1$. One can interpret this assumption by thinking at a population that consists of two groups: a group of undifferentiated unskilled workers and a group of skilled workers that differ in their capacities, low or high. The capacities in the skilled group can be more or less dispersed, we compare two cases: G, Germany, and U, the US, characterized by the following stylized distributions:

Skill Level	Weights	Stats
$\overline{h}^i$ with $\overline{h}^G < \overline{h}^U$	$(1-\psi)l^i$ with $l^U > l^G$	mean: $E(h^G) > E(h^U)$ var: $Var(h^G) < Var(h^U)$
$\underline{h}^i$ with $\underline{h}^G > \underline{h}^U$	$(1-\psi)(1-l^i)$	
1	ψ	

In order to simplify the assignment of *a certain* skilled workers to *a certain* machine, suppose that it is possible to sign a incentive compatible contract such that, for both entrepreneurs and skilled workers, is profitable to remain matched during all the $\underline{a}$ periods (for example, this can be the case if the pay increases with tenure). In this case, given the existence of capital-skill complementarity, the assignement problem of skills to machines is solved by attributing best workers to younger and more productive machines (see Kremer 1994 or Jovanovic 1998 for a detailed discussion).

The entrant invests up to the point where:

$$n_0 = c_0^{-1}\left\{V_0(h)\right\}$$

since now the value of the plant depends on skill quality[20].

The incumbent of age i has access to the backstop distant i from the leading-edge, but does not innovate since its productivity already depends on the skill level. So, the level of incumbents' investments is:

$$n_i = c_i^{-1}\left\{V_i(h)\right\}$$

Let turn now to show how differences in the skill distribution translates into differences in the employment distribution. To this end, note that the curve $c(n)$ is upward sloping in n, while $V(h)$ does not depend on n. So, there will exists a threshold value of n, n^* such that $c(n^*) = V(h)$. It is easy to see that n^* is an increasing function of h[21] (see fig. 8). This argument can be extended for firms of every age i.

We come out with an equilibrium sequence of investments and employment: $\{n_i\}$ with $i \leq k^j$ and $j = G, U$, where the new entrants draw from the pool of the high skilled workers; the incumbents of age 1 from the pool of the remaining workers and so on. In the realistic case where the low skilled are not endowed with enough human capital to work in the costly plants of new firms, a possible assignement of workers to plants is the following:

[20] The value of a plant is in this case if $a_0^+ > \underline{a}$: $V_0 = \int_0^{\underline{a}} e^{-(r-\delta)a}\left[(1-\alpha)\overline{h}\cdot e^{-\delta a}\right] da + \int_{\underline{a}}^{a_0^+} e^{-(r-\delta)a}\left[(1-\alpha)e^{-\delta a}\right] da + \int_{a_0^+}^{\overline{a}_0} e^{-(r-\delta)a}\left[e^{-(\delta a+i\delta)} - \underline{w}_i\right] da$

[21] $\partial V_i(h)/\partial h > 0$ for $i \geq 0$. Differentiating the free entry condition with respect to h, we get: $\partial n^*/\partial h = \partial V(h)/\partial h \cdot c^{-1}(V(h)) > 0$. Note that this result does not change if $\underline{a} > a^+$.

$$
\begin{aligned}
n_0 &= c_0^{-1}\left\{V_0(\overline{h})\right\} \leq (1-\psi)l\cdot N \\
n_1 &> (1-\psi)l\cdot N - n_0 \text{ and } n_1 < (1-\psi)l\cdot N - n_0 + (1-\psi)(1-l)\cdot N \\
n_i &= c_i^{-1}\left\{V_i(\underline{h})\right\} < (1-\psi)N - \sum^{i-1} n_j \\
n_k &= c_k^{-1}\left\{V_k(\underline{h})\right\} : n_{k+1} = c_{k+1}^{-1}\left\{V_{k+1}(\underline{h})\right\} < 0 \text{ or } (1-\psi)N - \sum^{k} n_j = 0
\end{aligned}
$$

Under these assumptions and using the fact that $n^*(h)$ is increasing function in h, , it is clear that: $\overline{h}^U > \overline{h}^G \Rightarrow n_0^U > n_0^G$; whereas for incumbents of age above 2 since $\underline{h}^U < \underline{h}^G$, we have that: $n_0^G > n_0^U$. Conversely, in Germany, a higher average skill compensates for the worse employment performance in highly innovative plants with a remarkably better performance in average productivity plants. It is interesting to stress that, consistently with the empirical evidence (Nickell and Bell 1996), the model predicts that the level of employment for skilled and unskilled does not tend to diverge as a response to technological shocks. The employment of both skilled and unskilled is a function of $\left\{n_i^j\right\}$, being equal respectively to $\sum_0^k \underline{a}\cdot n_i$ and $\sum_0^k(\overline{a}_i - \underline{a})\cdot n_i$, hence it is connected to investment behaviours as a function of the entry barriers and the shape of the skill distribution. Obviously, rigid labour market still affect investment decisions and employment; however, their impact is higher for unskilled workers through the shortening of the scrapping time $\overline{a}_i$.

From this excercise, some interesting considerations emerge. First, trivially, we have shown that different distribution of skills induces different distribution of investments; in particular, independetly from the size of the entry barriers and of from labour market institutions, in the US employment is more concentrated in new firms because the cohort of high skilled is larger. By noticing that new firms have a larger productivity dispersion, the lower observed dispersion of investments and productivity in Germany (Koeniger and Leonardi 2006) can be ascribed to differences in the skill distribution rather than to labour market institutions alone. Second, the different shapes of the skill distribution between the two areas amplify the pattern of wage inequality that would have prevailed in the case of similar skill distribution, but different labour market institutions. Indeed, larger differences in workers' skill translates into a higher dispersion of investments in machine of different quality. Finally, as we already showed, since in periods of more intense technical change the value of a plant used by older firms declines with respect to the value of a plant used by younger firms (see fig. 4), this implies that the unemployment performance deteriorates especially in countries that heavily rely on investments in old plants. This negative effect on employment can be further magnified by a bad design of post-secondary education (Amendola and Vona 2009, Vona and Consoli 2009), or by differences in the degree of regulation. Implicitly, in this model, the shape of the skill distribution co-determines the size of the entry barriers together with the cost differential between incumbents and entrants (fig. 11-12). As long as the cost of innovative activities depends on the size and the quality of the high skilled cohort, a more compressed skill distribution encompasses less incentives to invest in new plants. As a result, our model predicts that investments in highly innovative plants should be more sensible to regulation in countries with greater skill compression.

5.3 Endogenous Productivity Growth

Up to now we did not explain why systems with different innovation systems can grow at different rates. In fact, in steady state both systems grow at the rate δ and only differ in 'levels'. The extension to allow for differences in productivity growth is not problematic.

Consider a discrete-time economy. As before, production takes place in plant that employs 1 worker: $y_t(a,i) = A_t(a,i)$, where $A_t(a,i) = \Gamma^{-it} \cdot \Gamma^{t(\overline{a}-a)}$ and $\Gamma = 1+\delta$ is the index of productivity. If incumbents do not invest in innovation, we have that $g = \delta$. In this framework, we introduce the possibility that incumbents innovate using a variant of the production function that we use in the previous analysis. The new function, while keeping our main results unchanged, allows to account for different rates of productivity growth:

$$y_t(a,i) = [(p \cdot \lambda(n_0) + (1-p)) \cdot \Gamma]^{(k-i)t}$$

where now the learning capacity is not given exogeneously but is a function of a positive technological spillover of radical innovation in the economy $\lambda(\phi_0)$ where ϕ_0 is the fraction of workers employed in new plants with $\lambda'(\phi_0) > 0$ and $\lambda''(\phi_0) \to 0$ for $\phi_0 < \infty$. This assumption attempts to capture a more subtle implication of the Baumol idea of a division of the innovative labour: the extant ecology underlied by the division of innovative labour between entrants and incumbents. On the one hand, incumbents need entrants to experiment new technologies. On the other hand, both incumbents and entrants need innovations that, in vintage models, are the entrprenuers' weapon in the bargaining process. Indeed, without technological obsolescence, scapping never occurs, sunk costs are almost zero and, hence, the fundamental reason for the existence of entreprenuers disappears[22]. In sum, spillovers emerge since the incumbent innovative capacity depends on the technological opportunities, which are effectively created by entrants[23].

Going back to the analysis, the aggregate growth rate of the economy is a weighted average of the growth rate of different firms. More precisely, the system grows at the rate:

[22] The scrapping time tends to ∞ for $\delta \to 0$.
$lim_{\delta \to 0^+} \overline{a}_0 = lim_{\delta \to 0^+} \frac{1}{\delta} \log\left(\frac{1}{\underline{w}}\right) = \infty$.

[23] In this case it is possible to sort out the institutional configuration that maximizes growth. However, in this paper, we are not interested in the deviations from the first-best growth rate brought about by a certain institutional configuration.

$$g = \left\{ \lambda(\phi_0) \cdot \delta \cdot \sum_{i=1}^{k} p_i \phi_i \right\} + \left\{ \delta \cdot \sum_{i=0}^{k} (1 - p_i) \phi_i \right\}$$

where obviously $p_0 = 0$.

Since $\frac{d^2 g}{dp \cdot d\delta} < 0$ because the *effectiveness* of incumbent innovations is decreasing with the rate of technical change, we have that in correspondence to faster technical change a system more oriented towards incremental innovations, larger λ, suffers a larger decrease in its rate of growth than a system more oriented towards radical innovation where p is smaller.

6 Concluding Remarks

We build a vintage model with heterogenous firms in order to investigate the determinants of 'job creative destruction' in different parts of the job distribution. The main contribution of the paper is to build a new theoretical framework that is able to stress the endogeneity of an 'innovation regime' to entry barriers and the skill distribution. In particular, entry barriers are endogenous, depending on the incumbents' learning capacity and on innovation potential. When the innovation potential is larger, entry barriers should decrease so as to favour job creation in high tech job and foster productivity growth.

We first prove that an acceleration in the rate of capital embodied technical change is more harmful in an innovation system oriented towards increamental innovation. Following this acceleration, both employment and productivity deteriorate more in countries with an incremental-mode of innovation. Moreover, we show that, while differences in labour market institutions certainly play a preminent role in the explanation of wage inequality dynamics, other institutional parameters such as product market regulation, entry barriers and the skill distribution has a paramount impact in explanaining cross-country divergence in terms of productivity and employment.

Not surprising, the institutional adjustment to faster technical change is more painful in an innovation regime based on incremental innovation, involving larger institutional change to restore the pre-shock level of employment. Again, both employment and productivity falter if the wage floor is downward rigid and degree of product market regulation does not accommodate for the changes in the productive opportunities between entrants and incumbents. However, if only the wage floor accommodated for the faster technological depreciation–as prescribed by the standard view– the new productivity level would be significantly lower due to job relocation to low tech activities. In contrast, only a mild cut in the wage floor is required if the decrease in the investment costs–i.e. lower degree of regulation–ensures job relocation towards high tech activities; as a result, a higher productivity level is reached in the new steady state. This is consistent with the empirical evidence of certain countries (e.g. US, Sweden, Finland)that, in spite of the profound differences in labour markets, were able in last 10 years to expand employment at a non-decreasing productivity growth (Oecd 2007).

The paper can be extended in two directions. First, we did not investigate directly the impact of a selective policy that decreases the investment cost only for entrants; this is because we limit ourselves to a simplified model where the steady state level of entry barriers is determined endogenously given the other parameters. An extension of the model should consider this feature. Second, the transition from a steady state to another is far from being guarantee, hence out-of-equilibrium dynamics (Amendola and Gaffard 1998) should be included in a macroeconomic version of the model (with final demand) to investigate the conditions under which the transition is viable.

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A Appendix: Empirical Evidence

Expenditures edu. % GDP°					% pop. degree*	% post-sec. voc.§
	less than tert.		tertiary			
Country	1995	2004	1995	2004	1996	1996
US	3.9	4.4	2.4	2.9	26	–
UK	3.9	4.1	1.2	1.1	13	57
DE	3.7	3.5	1.1	1.1	13	76
FR	–	4.1	–	1.3	10	54
IT	–	3.4	0.7	0.9	8	72
FI	4.0	3.9	1.9	1.8	12	52
SWE	4.1	4.5	1.6	1.8	13	51
NED	3.0	3.4	1.4	1.3	23	70

Table 1: source Oecd, ∘all, *% of pop. 17-34, § at the highest age of up.-sec. enrol.

Student aids % of GDP		**Net cost**
Country	Student aids	%(GDP×cap)
U.S.	0.26	17.2
U.K.	0.39	24.5
DE	0.13	14.2
FR	0.14	18.9
IT	0.08	23.3
FI	0.36	8.4
SWE	0.32	1.6
NED	0.63	7.8

Table 2: source Oecd 2008 source Usher (2005)

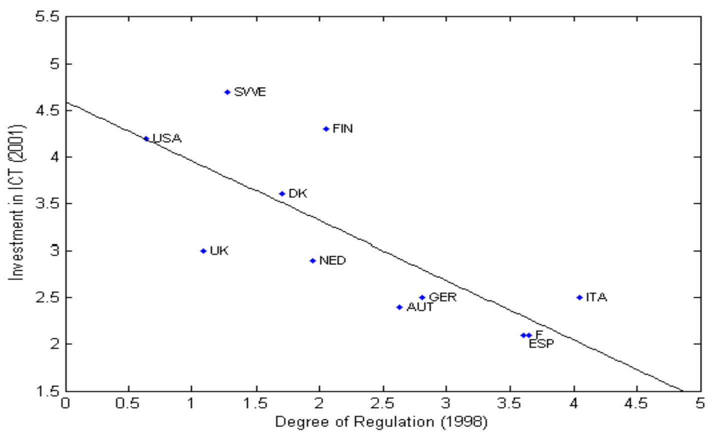

Figure 1 (from Duernecker 2008)

Table 5: Percentile distribution of test scores, US and Germany

	5th	25th	Mean	75th	95th
U.S. Average	133.5	234.6	272.3	319.4	370.8
Germany Average	208.2	255.4	281.4	316.5	359.3

Figure 2 (computations of Freeman and Schettkat 2003 from the International Adult Literacy Survey, Oecd 1997)

B Appendix: the Incumbent Problem

B.1 General Cost Functions

All results are unchanged as long as we assume that the cost function is increasing in the number of plants.

Consider: $c_i(n) = (\underline{c}+c(\chi))n_i^{\zeta}$ we have: $n_i = \left[\frac{p^i_\delta(\chi)\cdot\overline{V}_i(V_0)+(1-p^i_\delta(\chi))\cdot\underline{V}_i(V_0)}{(\underline{c}+c(\chi))}\right]^{1/\zeta}$

When we compare $n_{\chi>0}$ with $n_{\chi=0}$ we can raise both terms in the brackets by ζ so all comparisons remain unchanged.

From an economic point of view the justification of an increasing cost function is less intuitive. A first possibility is that entrepreneurs have different abilities, hence the effective cost is higher for less able entrepreneurs and quasi-rent are appropriated by entrepreneurs with an ability-threshold above a^* with a^* s.t. $c(a^*) = V^e$. A second possible explanation is the price of input required to carry on investments is increasing in its demand. This effect can be made explicit through the consideration of a construction phase where the market for the input required to build a new plant is considered.

B.2 Proofs

Proof, proposition 1. Let us prove the four statements seriatim:

i) In order to prove this condition, we compare the investments that would have occurred with and without incremental innovations: $n(\chi > 0) \gtreqless n(\chi = 0)$, in the three case of a linear, a concave and a convex cost of incremental innovations. Recall that the incentive constraint $n(\chi > 0) > n(\chi = 0)$ should be satified in order to have positive investments in incremental innovations. First conside the case of a linear cost function and rearranging the inequality $n(\chi > 0) \gtreqless n(\chi = 0)$, one obtains: $c \cdot \left(\frac{\chi}{i \cdot e^{\xi\delta}}(\overline{V}_i - \underline{V}_i) + \underline{V}_i\right) \gtreqless c\underline{V}_i + c_t\underline{V}_i \cdot \chi$. Or, after simple algebra, that $\frac{c}{i \cdot e^{\xi\delta}}(\overline{V}_i - \underline{V}_i) \gtreqless c_t\underline{V}_i$ which is either verified or not, so the firms invest 0 if $\frac{c}{i \cdot e^{\xi\delta}}(\overline{V}_i - \underline{V}_i) < c_t\underline{V}_i$, or $max(\chi_i)$, otherwise. Second consider a concave cost function of incremental innovations, that is: $c(\chi) = c_t\chi^\sigma$ with $\sigma < 1$. Firms decide to invest in incremental innovations iff $n(\chi > 0) > n(\chi = 0)$, in this case iff: $\chi_i < \left\{\frac{c}{c_t} \cdot \frac{1}{i \cdot e^{\xi\delta}} \cdot \left[\frac{\overline{V}_i - \underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$. By approximating $\overline{V}_i - \underline{V}_i$ with $(\lambda - 1)\underline{V}_i$ and rearranging, we get the condition: $\chi_i > \left\{\frac{c_t}{c} \frac{i \cdot e^{\xi\delta}}{(\lambda-1)}\right\}^{\frac{1}{1-\sigma}}$. Notice that firms do not over-invest in incremental innovations so $max(\chi_i) = i \cdot e^{\xi\delta}$. Moreover, it is realistic to assume that $\lambda - 1 < 1$ as otherwise the learning effect would generate leap-frogging for firms older than 1 or 2. So, provided that $\frac{c_t}{c}$ is not too small, $\left\{\frac{c_t}{c} \frac{i \cdot e^{\xi\delta}}{(\lambda-1)}\right\}^{\frac{1}{1-\sigma}} > max(\chi_i)$ that leads to a contradiction. In the third case of $\sigma < 1$, we get an internal solution as $\chi_i < \left\{\frac{c}{c_t} \cdot \frac{1}{i \cdot e^{\xi\delta}} \cdot \left[\frac{\overline{V}_i - \underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$ is verified for internal values of χ_i. The value $\left\{\frac{c}{c_t} \cdot \frac{1}{i \cdot e^{\xi\delta}} \cdot \left[\frac{\overline{V}_i - \underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$ is also the cutoff value for which $n(\chi > 0) > n(\chi = 0)$, therefore $\overline{\chi}_i = \left\{\frac{c}{c_t} \cdot \frac{1}{i \cdot e^{\xi\delta}} \cdot \left[\frac{\overline{V}_i - \underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$ is the locus of point for which $n(\chi > 0) = n(\chi = 0)$.

ii) To prove that the sequence $\{\chi_i^*\}$ is decreasing in the firm age i, let us differentiate the first order condition of the maximization problem $\max_\chi [n_i]$ with respect to i. The FOC of this problem is:

$$p_i(\overline{V}_i - \underline{V}_i)(c + c_t\chi_i^\sigma) - \sigma \cdot c_t\chi_i^{\sigma-1}(p_i \cdot \chi_i(\overline{V}_i - \underline{V}_i) + \underline{V}_i) = 0$$

where $p_i = \frac{1}{i \cdot e^{\xi\delta}}$.

Rearranging and using the approximation $\overline{V}_i - \underline{V}_i \simeq (\lambda - 1)\underline{V}_i$, it is easy to verify that: $\chi_i = \left[\frac{cp_i(\lambda-1)}{((c_t(\sigma-1)(\lambda-1) \cdot p_i\chi_i) + \sigma c_t)}\right]^{\frac{1}{\sigma-1}}$.

We then differentiate both sides with respect to i:

$\frac{d\chi_i}{di} = A\left(\frac{d\chi_i}{di}\right) \cdot B$ with $B = \frac{1}{\sigma-1}\left[\frac{cp_i(\lambda-1)}{(c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t}\right]^{\frac{1}{\sigma-1}-1} > 0$

$$A\left(\frac{d\chi_i}{di}\right) = \left[\frac{cp_i'(\lambda-1)\cdot((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)-cp_i(\lambda-1)\cdot\left(p_i'\cdot c_t(\sigma-1)(\lambda-1)\chi_i+\frac{d\chi_i}{di}p_i\cdot c_t(\sigma-1)(\lambda-1)\right)}{((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)^2}\right]$$

After some algebra, we get: $\frac{d\chi_i}{di} = B\cdot\left(1+\frac{p_i^2\cdot c\cdot c_t(\sigma-1)(\lambda-1)^2}{((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)^2}\right)^{-1} \times ....$

$\left[\frac{cp_i'(\lambda-1)\cdot((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)-cp_i'(\lambda-1)^2\cdot c_t(\sigma-1)p_i\chi_i}{((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)^2}\right] = ...$

$= B\cdot\left(1+\frac{p_i^2\cdot c\cdot c_t(\sigma-1)(\lambda-1)^2}{((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)^2}\right)^{-1}\left[\frac{cp_i'(\lambda-1)\cdot\sigma c_t}{((c_t(\sigma-1)(\lambda-1)\cdot p_i\chi_i)+\sigma c_t)^2}\right] < 0$ since $p_i' < 0$.

iii) Recall that, for $\sigma > 1$, $n(\chi > 0) > n(\chi = 0)$ iff $\chi_i^* < \overline{\chi}_i = \left\{\frac{c}{c_t}\cdot\frac{1}{i\cdot e^{\xi\delta}}\cdot\left[\frac{\overline{V}_i-\underline{V}_i}{\underline{V}_i}\right]\right\}^{\frac{1}{\sigma-1}}$. Since both χ_i^* and $\overline{\chi}_i$ are decreasing in i, taking the limit for $i\to\infty$, we have $\lim_{i\to\infty}\chi_i^* < \lim_{i\to\infty}\overline{\chi}_i = 0$. Therefore, there exists a k such that $\chi_k^* < \varepsilon$.

iv) Using the approximation $\overline{V}_i - \underline{V}_i \simeq (\lambda-1)\underline{V}_i$, the speed of convergence of $\left\{\frac{c}{c_t}\frac{\lambda-1}{ie^{\xi\delta}}\right\}^{\frac{1}{\sigma-1}}$ is inversely related to the learning capacity λ: in correspondence to a higher learning capacity, the threshold ε is reached later.

■

Proof, proposition 2. Rearranging, the FOC of the firm maximization problem reads:

$[p_ic-(\sigma-1)\cdot c_tp_i\cdot\chi_i^\sigma]\cdot(\overline{V}_i-\underline{V}_i) = \sigma\cdot c_t\chi_i^{\sigma-1}\cdot\underline{V}_i$. Since the gap between the high and the low option for the incumbent is clearly increasing in i, i.e. $\partial(\overline{V}_i-\underline{V}_i)/\partial\lambda > 0$, it is straighforward to see that also $\partial\chi_i/\partial\lambda > 0$ to ensure the optimality condition implicit in the FOC. ■

Proof, proposition 3. The proof is a more involved that the previous ones. Again, by differentiating the FOC with respect to δ:

$-\left(\frac{\xi c}{ie^{\xi\delta}}\right)\Delta V+\left(\frac{c}{ie^{\xi\delta}}\right)\frac{d(\Delta V)}{d\delta}-\left(\frac{\xi c_t}{ie^{\xi\delta}}\right)\Delta V\cdot(1-\sigma)\cdot\chi_i^\sigma+\left(\frac{c_t}{ie^{\xi\delta}}\right)(1-\sigma)\cdot\chi_i^\sigma\frac{d(\Delta V)}{d\delta}...$
$-\sigma\cdot c_t\chi_i^{\sigma-1}\cdot\left(\frac{d\underline{V}_i}{d\delta}\right) = \left((\sigma-1)\cdot c_t\chi_i^{\sigma-2}+\sigma(\sigma-1)\cdot\Delta V\cdot\chi_i^{\sigma-1}\right)\cdot\left(\frac{d\chi_i}{d\delta}\right)$

From this expression, it is easy to sort out the condition:

$$\left(\frac{d\chi_i}{d\delta}\right) > 0 \Leftrightarrow \left|\frac{d\underline{V}_i}{d\delta}\right| > -\frac{B\cdot\Delta V+F\cdot\left|\frac{d(\Delta V)}{d\delta}\right|}{D\cdot ie^{\xi\delta}}$$

where $D = \sigma\cdot c_t\chi_i^{\sigma-1} > 0$, $B = \xi c_t\cdot(\sigma-1)\chi_i^\sigma - \xi c$, $F = c_t\cdot(\sigma-1)\chi_i^\sigma - c$.

$\left|\frac{d\underline{V}_i}{d\delta}\right| > 0$ since $\frac{d\underline{V}_i}{d\delta} < 0$, while the sign of $\frac{d(\Delta V)}{d\delta}$ is less clear but the effect of technical change on the $\Delta V = \overline{V}_i - \underline{V}_i$ tends to be small and negative. B and

C have the same sign and can be either negative of positive. In the former case, $\left(\frac{d\chi_i}{d\delta}\right) > 0$. In the latter, it depends on the parameters and on the magnitude of the derivative w.r.t. δ. However, numerical analyses show that in the relevant range of the parameters, the effort for incremental innovations tends to increases with rate of technical change δ. ■

Proof, proposition 4. The effectiveness of the learning process tends to decrease, the sharper the distance between successive technologies. Note that $\partial\overline{V}_i(V_0)/\partial\delta < 0$ and $\partial\underline{V}_i(V_0)/\partial\delta < 0$, therefore it is very unlikely that the increase in χ^* allows to offset the worsening in the incumbent's environment. To see this, let us differentiate the expression of the expected plant value for the incumbent i, i.e. $V_i(\chi^*) = p^i_\delta(\chi^*)\cdot\overline{V}_i(V_0) + (1-p^i_\delta(\chi^*))\cdot\underline{V}_i(V_0)$, gettting: $\frac{\partial V_i(\chi^*)}{\partial\delta} = p'\cdot(\overline{V}-\underline{V}) + p\overline{V}' + (1-p)\underline{V}'$.

The last two terms are negative, the first depends on the sign of the derivative $\partial p^i_\delta(\chi)/\partial\delta$ which is positive only if the elasticity of incremental to radical innovations is large enough: $\epsilon_{\chi\delta} = (\partial\chi^*/\partial\delta)/\chi > \xi$. Overall we have that effect of an acceleration in the rate of technical change is positive for the investment of incumbent firms iff:

$$\epsilon_{\chi\delta} > \left[\xi + \left|\frac{(1-p)\underline{V}' + p\overline{V}'}{p(\overline{V}-\underline{V})}\right|\right]$$

Which is very unlikely to be verified as the elasticity of 'incremental' to 'radical' innovation should be to large for compensating for the sharp decrease in $V_i(\chi^*)$ brought about by a faster technical change. Obviously this condition is more likely to be verified the smaller is the depreciation of incumbent capacity over time, i.e. the smaller ξ.

Finally, we should prove that: $\frac{\partial n_0}{\partial\delta} > \frac{\partial n_i}{\partial\delta}$. For $i = 1$ this is equivalent to (by induction the proof can be easily extended for $i > 1$): $\left|V_0'\right| < \frac{\overline{c}}{c(\chi)+\underline{c}}\cdot \left|p_1'\cdot(\overline{V}_1-\underline{V}_1) + p\overline{V}_1' + (1-p)\underline{V}_1'\right| - \frac{\overline{c}}{(c(\chi)+\underline{c})^2}\left|p_1\cdot(\overline{V}_1-\underline{V}_1)+\underline{V}_1\right|\cdot(\partial c(\chi)/\partial\delta)$.

$(\partial c(\chi)/\partial\delta) > 0$ but very small. Moreover, by noticing that $\frac{\overline{c}}{c(\chi)+\underline{c}} > 1$ and that $p_1'\cdot(\overline{V}_1-\underline{V}_1)$ the additional effect due to a deterioration in the efficacy of the learning process (the probability of success for incremantal innovation is decreasing in $\delta : p_1' < 0$), the condition is verified in the relevante range of the parameters (see also the fig. 5). ■

B.3 Normalization and Steady State

In steady state, the free entry conditions for the entrant and the incumbent of age i are, respectively:

$$\begin{aligned} e^{\delta t}\cdot C_0(n_0) &= V_0(t) = e^{\delta t}\cdot V_0 \\ e^{\delta(t-i)}\cdot C_i(n_i) &= V_i(t) = e^{\delta(t-i)}\cdot V_0 \end{aligned}$$

Where the initial cost is adjusted to take into account of the distance from the technological frontier.

In steady state, the wage floor $\underline{w}$ should grow at δ. Therefore, if the wage floor is unique in each 'firm-sector', the scrapping condition for the incumbent i reads: $\pi(\overline{a}_i) = e^{-(\delta\overline{a}_i + i\delta)} - \underline{w} = 0 \rightarrow \overline{a}_i = \frac{1}{\delta}\log\left(\frac{1}{\underline{w}}\right) - i$.

Obviously, the assumption of a unique wage floor has a negative impact on the propensity to invest of incumbents and hence reduce the scrapping time of older firms. However, as in MW 1997, a unique wage floor can have a positive effect on the process of job creative destruction by increasing the scope of job relocation from low to high tech industries. Otherwise, wage floors are firm-specific with: $\underline{w}_i = \underline{w}_0/e^{i\delta}$. And the sector-specific wage floors affect scrapping uniformly across the economy: $\pi(\overline{a}_i) = e^{-(\delta a + i\delta)} - \underline{w} \cdot e^{-i\delta}$ so scrapping is unaffected by the firm age: $\overline{a}_i = \frac{1}{\delta}\log\left(\frac{1}{\underline{w}_0}\right) = \overline{a}_0$.

C Figures and Tables

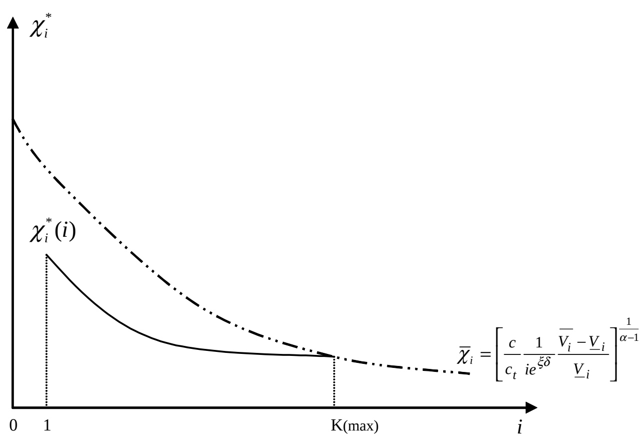

Figure 3

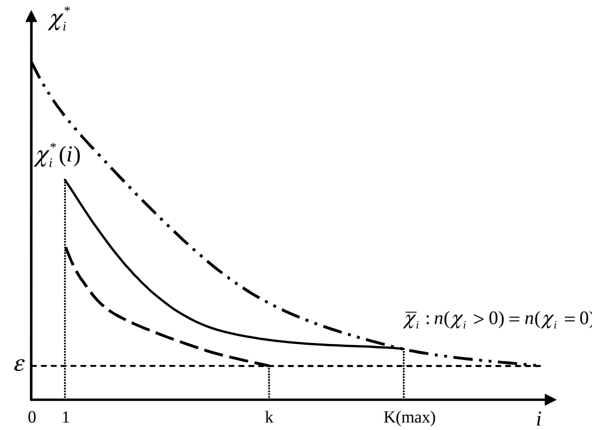

Figure 4

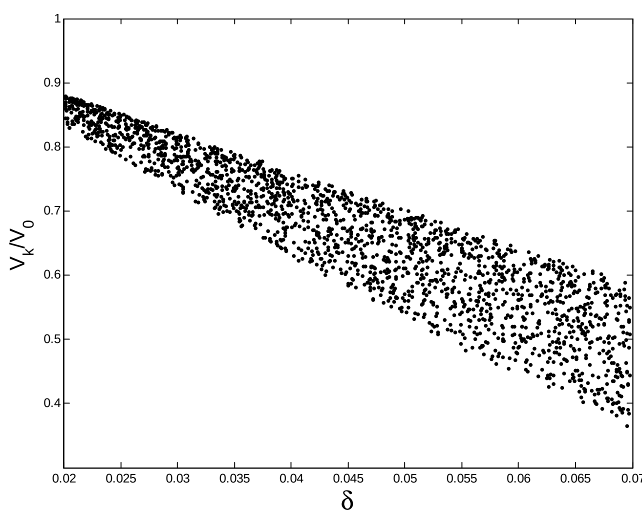

Figure 5

Age/Quality	0	$(0,1)$	...	$(\overline{a}^e_{k-1+1},\overline{a}^e_{k-1})$	$(\overline{a}^e_{k-1},\overline{a}^e_{k-2})$	...	$(\overline{a}^e_2,\overline{a}^e_1)$	$\overline{a}_1$
0	n_0	n_0	...	n_0	n_0	...	n_0	n_0
1		n_1	...	n_1	n_1	...	n_1	
$\vdots$				...	...	...		
i			...	n_i	n_i	n_i		
$\vdots$				...	...	...		
$k-1$				n_{k-1}	n_{k-1}			
k				n_k				

Table 3

$\mathbf{w}_{\min}$	$\boldsymbol{\alpha}$	$\boldsymbol{\lambda}$	$\boldsymbol{\delta}_0$	$\mathbf{w}_{50/10}$	$\mathbf{w}_{90/50}$	$\mathbf{w}_{90/10}$
.05	.60	1.1	.02	2.73	3.25	8.89
–	–	1.4	–	2.79	3.25	9.06
–	–	1.1	.045	2.72	3.22	8.76
–	–	1.4	–	2.59	3.22	8.37
.10	.55	1.1	.02	1.76	2.46	4.33
–	–	1.4	–	1.72	2.51	4.33
–	–	1.1	.045	1.79	2.46	4.40
–	–	1.4	–	1.71	2.35	4.01
.15	.48	1.1	.02	1.25	2.09	2.62
–	–	1.4	–	1.22	2.09	2.57
–	–	1.1	.045	1.24	2.05	2.56
–	–	1.4	–	1.19	1.96	2.33
.20	.42	1.1	.02	1	1.79	1.79
–	–	1.4	–	1	1.75	1.75
–	–	1.1	.045	1	1.75	1.75
–	–	1.4	–	1	1.53	1.53

Table 4: unique wage floor, comparative static

$\mathbf{w}_{\min}$	$\boldsymbol{\alpha}$	$\boldsymbol{\lambda}$	$\boldsymbol{\delta}_0$	$\mathbf{w}_{50/10}$	$\mathbf{w}_{90/50}$	$\mathbf{w}_{90/10}$
.08	.60	1.1	.02	2.17	2.72	5.90
–	–	1.4	–	2.21	2.77	6.14
–	–	1.1	.045	2.22	2.69	5.98
–	–	1.4	–	2.33	2.69	6.26
.10	.55	1.1	.02	1.76	2.51	4.41
–	–	1.4	–	1.83	2.51	4.59
–	–	1.1	.045	1.78	2.57	4.59
–	–	1.4	–	1.95	2.46	4.80
.15	.48	1.1	.02	1.30	2.09	2.73
–	–	1.4	–	1.33	2.14	2.84
–	–	1.1	.045	1.36	2.05	2.79
–	–	1.4	–	1.42	2.15	3.06
.20	.42	1.1	.02	1.04	1.79	1.86
–	–	1.4	–	1.13	1.75	1.98
–	–	1.1	.045	1.14	1.75	2.00
–	–	1.4	–	1.31	1.68	2.19

Table 5: firm-specific wage floor, comp. static

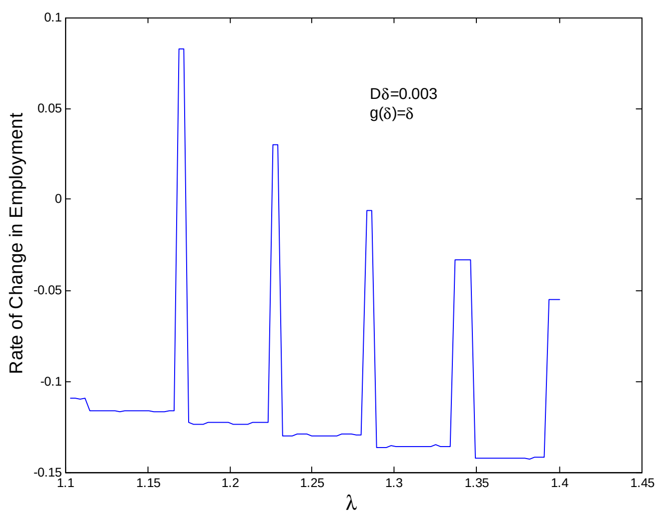

Figure 6: $dL(\lambda)/d\delta$, small shock comp. statics

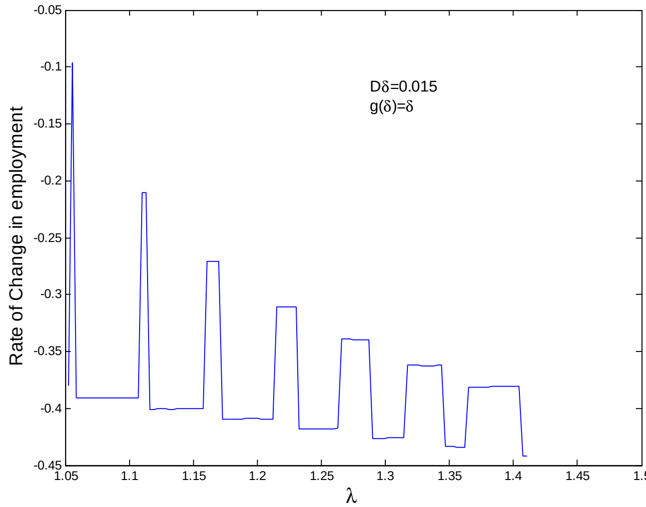

Figure 7: $dL(\lambda)/d\delta$, large shock comp. statics

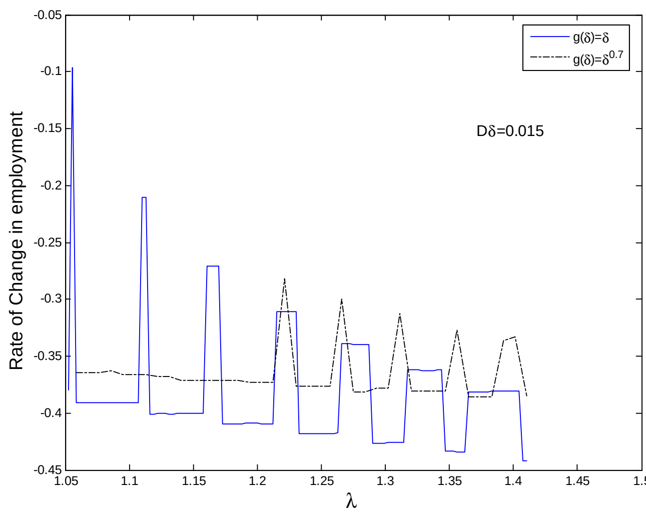

Figure 8: different depreciation scenarios

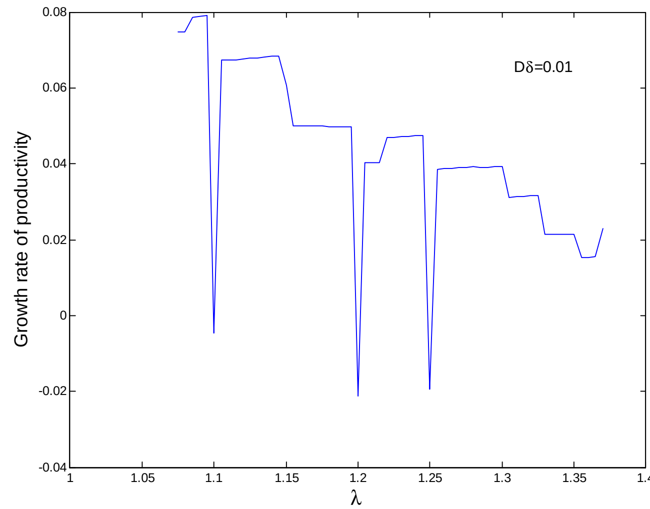

Figure 9: effect on prod. of a large shock, comp. stat.

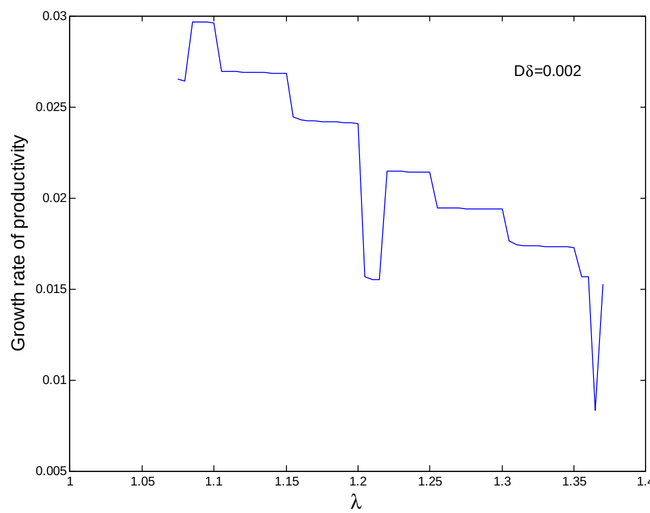

Figure 10: effect on prod. of a small shock, comp. stat.

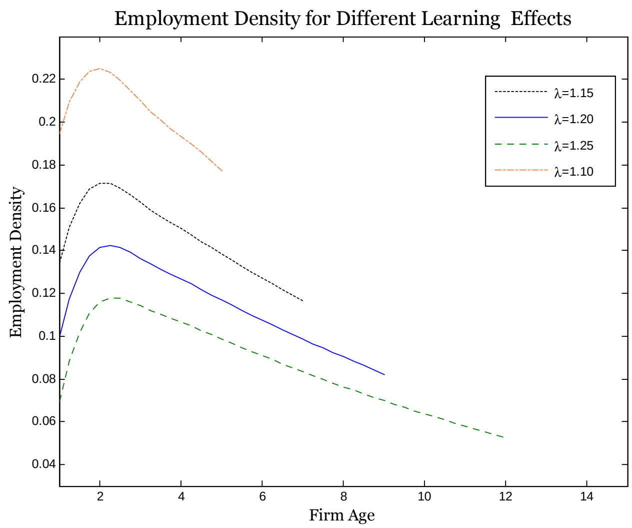

Figure 11

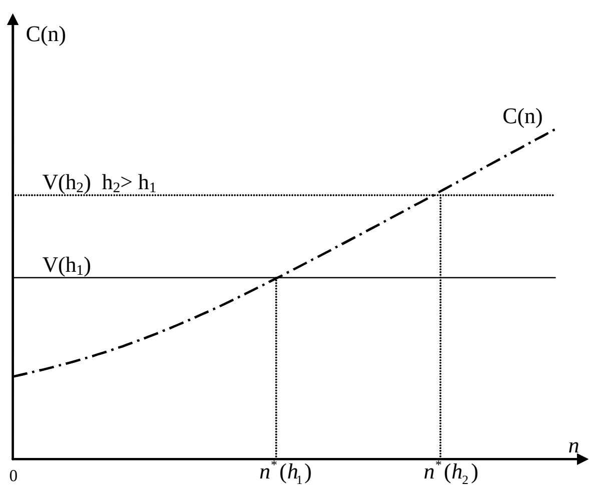

Figure 12: skill distribution and investments

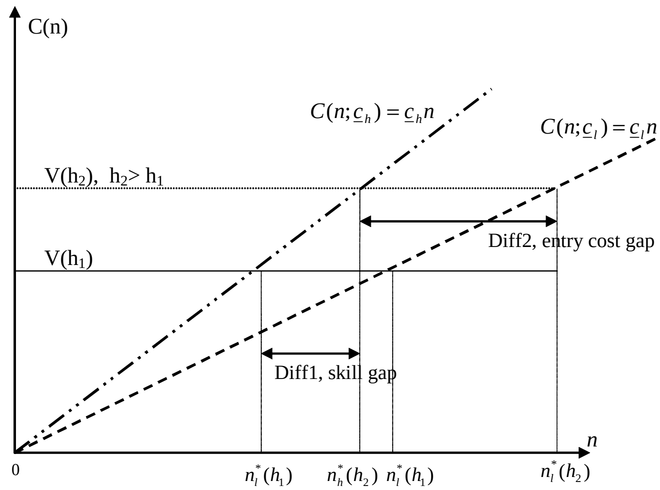

Figure 13: Skill distribution, entry barriers and investments

C.1 Adjustment

→US-type $d\delta = 0.01, w_{\min} = 0.10, \alpha = 0.55, \lambda = 1.15, \delta_0 = 0.02$

→EU-type $d\delta = 0.01, w_{\min} = 0.17, \alpha = 0.45, \lambda = 1.30, \delta_0 = 0.02$

#1 is the benchmark case. ΔInst1 is $\mathbf{dw}_{\min}$, ΔInst2 is decentralization, ΔInst3 is deunionization, ΔInst4 is a change in investment costs.

Tab. 6: US-type specific wage floors, g growth rate

#	ΔInst1:dw$_{\min}$	ΔInst2	ΔInst3	ΔInst4: inn reg	gL	gQ	$gw_{5/1}$	$gw_{9/5}$
1	–	–	–	–	$-.33$	.08	.03	$-.01$
2	$gw^*_{\min} = -.5$	–	–	–	0	$-.23$	.44	.36
3	$gw^*_{\min} = -.68$	$g\alpha^* = .1$	–	–	0	$-.32$	.95	.61
4	$gw^*_{\min} = -.4$	α	$g\alpha^* = -.1$	–	0	$-.17$	.16	.25
5	$gw^*_{\min} = -.15$	–	α	$g\bar{c} = g\underline{c} = -.42$	0	.07	.15	.01

Tab.7: EU-type specific wage floors, g growth rate

#	ΔInst1: $\mathbf{dw}_{\min}$	ΔInst2	ΔInst3	ΔInst4: inn reg	dL	dQ	$dw_{5/1}$	$dw_{9/5}$
1	–	–	–	–	$-.35$	.05	.01	.03
2	$gw^*_{\min} = -.6$	–	–	–	0	$-.26$	.58	.41
3	$gw^*_{\min} = -.66$	$g\alpha^* = .1$	–	–	0	$-.29$	.88	.50
4	$gw^*_{\min} = -.5$	α	$g\alpha^* = -0.18$	–	0	$-.19$	.21	.30
5	$gw^*_{\min} = -.3$	–	α	$g\bar{c} = g\underline{c} = -.55$	0	.09	.20	.09

Tab. 8: US-type,unique wage floors, g growth rate

#	ΔInst1: $\mathbf{dw}_{\min}$	ΔInst2	ΔInst3	ΔInst4: inn reg	gL	gQ	$gw_{5/1}$	$gw_{9/5}$
1	–	–	–	–	−.33	.08	.01	−.01
2	$gw^*_{\min}= -.57$	–	–	–	0	−.24	.52	.36
3	$gw^*_{\min}= -.71$	$g\alpha^*= .1$	–	–	0	−.3	.95	.57
4	$gw^*_{\min}= -.35$	α	$g\alpha^*= -.16$	–	0	−.12	.06	.17
5	$gw^*_{\min}= -.16$	–	α	$g\bar{c}= g\underline{c}= -.44$	0	.04	.07	.10
6	$w_{\min}$	–	$g\alpha^*= -.12$	$g\bar{c}= g\underline{c}= -.25$	0	.08	−.11	.01

Tab. 9: EU-type, unique wage floor, g growth rate

#	ΔInst1: $\mathbf{dw}_{\min}$	ΔInst2	ΔInst3	ΔInst4:inn reg	gL	gQ	$gw_{5/1}$	$gw_{9/5}$
1	–	–	–	–	−.38	.11	.02	−.06
2	$gw^*_{\min}= -.55$	–	–	–	0	−.24	.52	.33
3	$gw^*_{\min}= -.62$	$g\alpha^*= .1$	–	–	0	−.28	.77	.44
4	$gw^*_{\min}= -.45$	α	$g\alpha^*= -.18$	–	0	−.18	.08	.25
5	$gw^*_{\min}= -.27$	–	α	$g\bar{c}= g\underline{c}= -.56$	0	.09	.22	.12
6	$gw^*_{\min}= -.17$	–	$g\alpha^*= -.3$	$g\bar{c}= g\underline{c}= -.3$	0	.06	−.14	−.02