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Abstract

In a two-period model, firms specialized in two different sectors lobby to induce the government to subsidize the type of education complementary to their production. Lobbying is endogenous. We show that, if lobbying is not costly, both sectors will lobby in equilibrium and education policy will induce the same skill composition that would be chosen by the social planner. However, if lobbying is costly, only one sector finds it profitable to offer monetary contribution and direct resources towards the type of education required by its production. Which sector will engage in lobbying depends on relative size, productivity and price in the two sectors.

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1 Introduction

Modern economies devote a relevant share of their resources to education. However, even OECD countries differ not only in the share of GDP devoted to education, but also in the composition of education expenditures, in the graduation rate and in the distribution of graduates by level of education (primary/secondary vs tertiary), by program orientation (vocational vs general) and by field of education (cfr. tables 1 and 2). In countries such as the United States, United Kingdom and Canada, the education system is mainly oriented towards general rather than vocational programmes. Differently, Germany, Finland, Italy, and many others, have a relevant share of students enrolled in vocational programmes. As for the share of graduates by field of education, countries such as Korea, Finland and Sweden have a high share of graduates in engineering, while the United States, Luxemburg, Australia and New Zealand have a high share of students graduating in business.[1]

In this paper, we argue that differences in the composition of human capital are related to the production structure of the economy and we emphasize the potential key role of firms' political pressure activity. Skills are required by firms according to their needs and are acquired through the education system, whose outcome is a composition of human capital by level, field and program orientation. In a rapidly changing economy there is high demand for workers equipped with general skills, which are more mobile and can easily be adapted in new sectors. Analogously, the distribution by field of education should reflect the sectoral composition of the economy. Economies endowed with a higher share of human resources in science and technology are in a better position to innovate and expand production in high-tech sectors. On the other hand, if a relevant share of firms is specialized in high-tech production, demand for graduates in science and engineering

[1] Notice also that in Sweden 17% of students in 2008 graduated in engineering, manufacturing and construction; among them, 78% graduated in engineering. Analogously, in the United States, 40% of students graduated in social science, business and law; of them, 54% graduated in business. Even more striking are the differences among the shares of graduates by field of education relative to total population. In the United States, of the relatively low number of graduates for 1000 inhabitants (7.7) 3 graduated in social science business and law (SSBL) and 0.5 in engineering, manufacturing and construction (EMC). In Korea instead, of the 8.2 graduates for 1000 inhabitants, 1.9 graduated in SSBL and 1.9 in EMC.

is correspondingly high. Thus, the direction of causality is difficult to identify and the relationship is probably not one-way.

Table 3 reports, for the year 2006, the sectoral composition of production for 30 OECD countries. Countries such as Korea, Finland and to a certain extent also Ireland and Japan, have a high share of production in manufacturing, focused on high and medium-high tech, and a relatively lower share of value added in services. On the other hand, United States, United Kingdom and France have high share of production in services, mainly in finance insurance and business services.

As shown in figures 1 and 2, there appears to be a positive correlation between countries productive specialization and the composition of graduates by field of study. Figure 1 plots the shares of graduates in science and engineering in association with the share of value added in high-tech sectors. Figure 2 plots the share of graduates in social science, business and law in 2008 in association with the share of value added in finance, insurance and business services. However, the two diagrams, and the value of R-squared, also indicate that a relevant fraction of the variance remains unexplained. This suggests that something else, beside an economy's sectoral composition, is needed to account for differences in the composition of human capital.

In this paper, we ask whether the missing ingredient may be related to politics and to political economy aspects. We start from the observation that lobbying activity may be very intensive in some country. In the US for instance (but similarly in Canada), universities, companies, labor unions, and other organizations spend billions of dollars each year to lobby Congress and federal agencies. In 2010 total lobbying spending was $2.61 billion with a total number of 12488 lobbyists (Open Secrets, 2010). Among the top spenders we find several companies. We also know that many lobbying groups have focused on the improvement of education (which is among the top ten issues with more than one thousand clients per year) and degrees awarded by students in specific fields (Carlson, 2005). As reported by the Center for Responsive Politics (Open Secrets, 2010) in the US, which, as we already noticed, have a high share of students graduating in business and a high share of production in finance insurance and business services, in 2010 insurance industries have spent $120,627,007 and business associations have spent

$105,003,616 in lobbying activities.[2] The amount spent in lobbying activities by these two sectors ranks first among the industry sectors.[3] If companies in insurance and business lobby for more spending in education for business, lobbying activity may play a role in shaping the relation between the type of education and the structure of production.

We analyze the political economy of education in a setting in which firms specialized in (two) different sectors try to induce the government to finance the type of education which is complementary to their production. In our two-period model, there is a continuum of firms specialized in one of the two sectors and a continuum of workers who live for two periods. In each sector, firms use as production-input labour of a given skill-type. In the first period, individuals choose which type of education to acquire; this determines the skill composition of workers in the second period. Education is subsidized by the government. Firms may lobby the government to influence its education policy so as to obtain a favorable skill composition of the labour force. Following Bernheim and Winston's (1986) common agency approach, firstly applied in economics by Grossman and Helpman (1994), we assume that firms can offer monetary contributions to the policy-maker conditional on the structure of education subsidies chosen. Moreover, following a more recent strand of the literature (Baldwin and Robert-Nicoud, 2007), we allow for endogenous lobbying. We are able to show that, if there are no costs of lobbying, then both sectors will lobby in equilibrium. In this political equilibrium the policy-maker chooses the same skill composition that would be chosen by the social planner. However, if lobbying is costly, as it is more realistic to assume, it may be that only one sector will find it profitable to offer monetary contributions. This is the sector with a higher relative weight, measured by relative size, productivity and price. Thus, the lobbying activity may contribute to explain differences in educational systems across economies.

The rest of the paper is organized as follows: next section reviews the related literature; section 3 presents the model and section 4 derives the political equilibrium with endogenous lobbying; section 5 concludes. All proofs are in the appendix.

[2] Open Secret's lobbying database is available on line at http://www.opensecrets.org/lobby/

[3] The same is true if we take the total value of spending in the period 1998-2010.

2 Related literature

Our paper brings together different strands of the literature. It contributes to the political economy of education by investigating the possibility that education policy responds to the interest of firms exerting pressure on the policy-makers in order to obtain their favorite human-capital composition. The political economy approach has mainly focused on the redistributive role of education and on income distribution as the main determinant of educational policy (see Di Gioacchino and Sabani, 2009). In this paper, we abstract away from education's redistributive role and focus on its effect on the "production" of skills. Thus, the conflict of interest is not among income groups but between firms active in different sectors and interested in the supply of different skills. Our results point to the possibility of multiple equilibria with different mix of education and production.

The focus on the complementarity between education and the structure of production closely relates our paper to the recent literature on the "varieties of capitalism" (Hall and Soskice, 2001, Iversen, 2005) which emphasizes how workers' investment in skills, firms' international product market strategies, social protection and electoral politics reinforce each other to determine a "welfare production regime".[4] So, the relative abundance of certain skills constitute a comparative advantage for firms that use those skills. Therefore, firms, interested in specific skills will support education policies that ensure an adequate return for workers who invest in those skills and social policies that protect this investment. Along this lines, we explicitly model firms' active political role in shaping education policy through lobbying.

The idea that the educational structure is functional to the interest of firms (the capitalist class) can be found in Bowles (1978) and more recently in Galor and Moav (2006).[5]

[4] See also Bénabou (2003), where the distribution of human capital, technological choice and redistributive institutions are simultaneously determined. Unlike ours, in his paper firms do not try to influence the distribution of human capital, which they take as given when choosing (the degree of flexibility in) their technology.

[5] The role of social conflict in shaping the educational system has also been stressed by Bertocchi and Spagat (2004). Other studies have identified different sources of conflict between social classes, related for instance to social mobility (see Bernasconi and Profeta, 2007).

They argue that due to capital-skill complementarities, the accumulation of physical capital in the process of industrialization increased the importance of human capital and generated incentives for capitalists to support the provision of universal education. Our paper is tightly related to Galor and Moav (2006); as in their work, we view the educational system as the upshot of political and economic conflicts; however, we assume heterogeneity in the human capital used in different industries and thus allow for a conflict of interests among capitalists. Moreover, differently from previous contributions, we use lobbying to characterize the political process and we develop an endogenous lobbying model.

Our paper is also related to the recent literature on the interplay among human capital, technology, the structure of production and economic growth.[6] Since Nelson and Phelps' 1966 seminal paper, it has been recognized that a more educated labour force would adopt new technologies faster and, at the same time, the demand for skill would increase as new technologies are introduced (Acemoglu, 2002). This literature points out the possibility of multiple equilibria. One equilibrium is characterized by high levels of human capital, faster adoption of new technologies and high share of production in high-tech industries, while the other equilibrium depicts low levels of human capital, higher distance from the "technological frontier" and production specialized in traditional sectors. A strand of this literature has recognized the importance of distinguishing between different types of human capital. Vandenbussche et al. (2006) have shown the growth-enhancing effects of tertiary education, especially for economies close to the technological frontier. Murphy et al. (1991) have demonstrated that the allocation of talent has significant effects on the growth rate of an economy. The reason is that economies which reward entrepreneurship more than rent seeking activities attract talented people in the more productive sectors. Using data on college enrolment in law as a measure of talent allocated to rent seeking activities, and on college enrolment in engineer as a measure of talent allocated to entrepreneurship, their empirical evidence confirms that countries with high proportion of engineers grow faster than countries with high proportion of lawyers. Although not relating it to growth,

[6] On the macroeconomic side and the evolution of wage inequality, see also the literature on the role of the skilled-biased technological change as responsible of the increase in the US skill premium (Krusell et al., 1999).

we reach a similar conclusion when discussing the individuals' choice of education. More recently, in a model of growth with households' education choice and costly technological adoption by firms, Krueger and Kumar (2004a, 2004b) have argued that an economy whose policies favour skill-specific, vocational education, will growth slower than an economy whose policies favour general education. As in their model, individuals decide which type of education to acquire. However, differently from them, in this paper we set aside technological progress, thus limiting firms' economic role, to emphasize firms' political role in directing education spending.

3 The model

The economy is populated by firms and individuals. Firms are a continuum of measure one and live indefinitely. Each firm is owned by a single entrepreneur. Individuals are a continuum of measure one and live for two periods.

The government finances skill formation through subsidies targeted to the acquisition of different education types. In the first period of their lives, given government subsidies, agents decide which type of education to obtain. In the second period they inelastically supply labour and are hired by firms in the sector that use as input the skill they have acquired. Firms may try to influence the government's education policy by exerting lobbying activity.

We restrict our attention to a two-sector and two-education type economy. Let γ be the fraction of firms in the first sector (f) and using workers with the first type of education (F) and $1-\gamma$ be the complementary set of firms, producing in the second sector (s) and using the second type of human capital (S).[7] We indicate by δ the share of workers with skill type F and by $1-\delta$ the complementary share of workers with skill type S.[8] All firms in the same sector are identical.

[7] We will suggest some interpretation of the results for two sectors with high and low productivity, but the model itself is more general. The two sectors may differ for the goods produced (e.g. service vs manufacture) or for the use of general vs specific skills or they may differ along other dimensions.

[8] The model is quite general. The two types of education may represent different fields (e.g. business vs engineering) as well as different programme orientation (general vs vocational) etc.

3.1 Firms

Firms' unique production input is labour. Recalling the definition of δ and γ, each representative firm in sector f employs $\frac{\delta}{\gamma}$ workers and each representative firm in sector s employs $\frac{1-\delta}{1-\gamma}$ workers. Let A_f, A_s denote the level of labour-augmenting technology in sector f and s, respectively so that if workers with the first type of education are more productive than workers with the second one, we expect A_f to be larger than A_s.

Thus, output for each representative firm in the two sectors is, respectively:

$$y_f = A_f \left(\frac{\delta}{\gamma}\right)^{\alpha} \tag{1}$$

$$y_s = A_s \left(\frac{1-\delta}{1-\gamma}\right)^{\alpha} \tag{2}$$

where $\alpha \in (\frac{1}{2}, 1)$.

Total output in the two sectors and in the whole economy are, therefore:

$$Y_f = \gamma y_f = \gamma^{1-\alpha} A_f \delta^{\alpha}$$

$$Y_s = (1-\gamma) y_s = (1-\gamma)^{1-\alpha} A_s (1-\delta)^{\alpha}$$

$$Y = \gamma^{1-\alpha} p_f A_f \delta^{\alpha} + (1-\gamma)^{1-\alpha} p_s A_s (1-\delta)^{\alpha} \tag{3}$$

where total output price has been normalized to one and p_f and p_s denote (relative) prices in the two sectors.

Labour market is competitive and workers are paid their marginal productivity; thus wages for sector f and s are, respectively:[9]

$$w_f = \alpha \gamma^{1-\alpha} A_f p_f \delta^{\alpha-1} \tag{4}$$

and

$$w_s = \alpha (1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha-1} \tag{5}$$

Notice that a worker's wage depends positively on the size, productivity and price of the sectors he is employed in and it is inversely related to the share of the population which holds his same skill.

[9] If final output is taken as numeraire, real wages are the same as monetary wages.

Each representative firm in the two sectors earns profits given by

$$\pi_f = (1-\alpha) A_f p_f \left(\frac{\delta}{\gamma}\right)^{\alpha} \tag{6}$$

and

$$\pi_s = (1-\alpha) A_s p_s \left(\frac{1-\delta}{1-\gamma}\right)^{\alpha} \tag{7}$$

Using Eq. (4) and Eq (5) , we can write the relative wage as follows:

$$\frac{w_s}{w_f} = \left(\frac{1-\gamma}{\gamma}\right)^{1-\alpha} \frac{A_s}{A_f}\frac{p_s}{p_f}\left(\frac{\delta}{1-\delta}\right)^{1-\alpha} \tag{8}$$

where $\frac{1-\gamma}{\gamma}$measures the relative size of the two sectors, $\frac{\delta}{1-\delta}$ measures the relative scarcity of the two types of workers, $\frac{A_s}{A_f}$ measures the relative productivity and $\frac{p_s}{p_f}$ the relative price in the two sectors.[10]

We summarize the "relative importance" of the two sectors by the parameter x:

$$x \equiv \frac{1-\gamma}{\gamma}\left(\frac{A_s}{A_f}\frac{p_s}{p_f}\right)^{\frac{1}{1-\alpha}} \tag{9}$$

which depends on the relative size, price and productivity of the two sectors. In what follows we assume that productivity, price and size of the two sectors are exogenous, and thus profits only depend on the labour force skill composition, δ. This leaves little economic role for firms but allows us to concentrate on the firms' political role.[11] In the next section, we will explain how δ is determined by individuals' decision, which is in turn influenced by the government's education policy, and discuss why firms may lobby to influence the government's education policy to their advantage.

3.2 Individuals

Following Krueger and Kumar (2004a and 2004b), we consider a continuum of two-period lived agents with total mass one who differ in their innate talent $t \in [0, 1]$, which is

[10] The same variables also determine relative profits in the two sectors.

[11] Having exogenous prices, is a clear, although in our context innocuous, simplification. What we have in mind is a non-competitive goods market structure. For example, assuming monopolistic competition, one could easily derive the relative price (see Baldwin and Robert-Nicoud, 2007, but also Acemoglu 2002). On the other hand, to endogenize firms' economic role in technology adoption and sector shift would require to specify a dynamic model, a task which we leave to future research.

uniformly distributed across the population with a cumulative distribution function $F(t) = t$.

In the first period of his life, an agent can opt to obtain either education of type F or education of type S. An agent who acquires skill F will be employed in sector f and earn a wage w_f in the second period of life [12]. An agent who acquires skill S, will work in sector s and earn wage w_s in the second period of life. Each agent receives a subsidy Σ_J by the government related to the specific type of education $J = F, S$ that he acquires.

Preferences are logarithmic. We assume that an agent with talent t who chooses the education type $J = F, S$ and will be employed in sector $j = f, s$ has the following utility function:[13]

$$U_J(t) = \log(w_j) + \log(\Sigma_J) - \log e_J(t) \tag{10}$$

where $e_J(t)$ is the cost of obtaining education of type J.[14] Thus, an agent with talent t, will choose education of type S iff:

$$\frac{w_s \Sigma_S}{w_f \Sigma_F} > \frac{e_S(t)}{e_F(t)} = e(t) \tag{11}$$

Assuming $e(t)$ is strictly decreasing (increasing), there exists a threshold level t^* such that agents with $t > t^*$ choose education of type S (F). Without loss of generality, in what follows we restrict attention to the case in which $e(t)$, that is the relative cost of obtaining education of type S, is strictly decreasing.[15] Thus, the share of workers with skill type F is $\delta = 1 - t^*$.

The analysis above suggests that the allocation of talents to sectors is jointly determined by the market, which establishes relative wages, and by education policy.

[12] The agent's task-specific productivity is at his highest value because the agent has received training for the specific technology adopted in sector f.

[13] The specification of the utility function follows closely Krueger and Kumar (2004b). In particular, as in their formulation, subsidy yields utility directly (for a rationalization of this, see footnote 18 in Krueger and Kumar, 2004b).

[14] This takes into account pecuniary and non-pecuniary costs and returns, including the consumption value of education. For an analysis of the choice of educational type which takes into account the consumption value of education see Alstadsaer et al. (2008)

[15] That is we focus on the case in which education of type S requires higher talent than education of type F.

3.3 The government

We assume that the government's objective function is a weighted sum of aggregate social welfare Δ and total lobby contributions C:

$$\Omega = \Delta + aC \tag{12}$$

where a is the relative weight given by the government to lobby contributions.[16] The higher is a, the higher is government "affinity" for political contributions and the lower is its concern for social welfare.

As in the standard case of an utilitarian social welfare function, Δ is specified as the sum of total workers' wage income in the two sectors ($W_f = \gamma w_f$ and $W_s = (1-\gamma)w_s$) and firms' profits in the two sectors ($\Pi_f = \gamma\pi_f$ and $\Pi_s = (1-\gamma)\pi_s$). Specifically, we have that:

$$\Delta = W_f + W_s + \Pi_f + \Pi_s \tag{13}$$

We assume that the government spends a total amount G, exogenously given, on education subsidies for the two types of education, Σ_F and Σ_S respectively.[17] The government's budget constraint is thus:

$$\delta\Sigma_F + (1-\delta)\Sigma_S = G \tag{14}$$

Given the available resources G, the government only chooses the allocation of subsidies between the two types of education. Recalling the condition for the individual's choice of education at Eq. (11) and the expression for the relative wage at Eq. (8), it follows that, given the sectors "relative importance" x, the government's allocation of subsidies uniquely determines δ. Accordingly, in the rest of the paper, we consider δ as the government's policy variable.

[16] Notice that both Δ and C depend on the educational policy, as it will be specified in the next sections.

[17] G is here taken as exogenous. As suggested by Kruger and Kumar (2004), one can imagine that the government collects taxes to finance education, through a proportional labour income tax. If preferences are logarithmic, what matters for the educational decision is the ratio of wages which is not affected by a proportional tax. Alternatively, one can imagine that firms finance education spending of new workers by paying a lump-sum tax which, again, does not affect their behaviour (see Di Gioacchino and Profeta, 2010).

3.4 The social planner

We first analyze the case of $a = 0$, i.e. the government puts no weight on lobby contributions and it behaves as a benevolent social planner. In this case $\Omega = \Delta$ as defined at Eq. (13).

Using Eq.(4), (5), (6), (7), the social planner's objective function can be rewritten as follows:

$$\Delta(\delta) = \gamma^{1-\alpha} A_f p_f \delta^{\alpha} + (1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha} \tag{15}$$

The efficient mix of the two types of education coincides with the decision of the social planner, who chooses δ in order to maximize Eq.(15). Solving the first order condition (see the appendix), and remembering the expression of x at Eq.(9) we obtain the following level of δ :

$$\delta_{PL} = \frac{1}{1+x} \tag{16}$$

Obviously, δ_{PL} is decreasing in x: the higher is sector s weight, relative to sector f, the more it is efficient to allocate resources to type S education than to type F.

4 The lobbying game

The previous section has shown that the mix of the two types of education that would be chosen by the social planner depends on the "relative importance" of the two sectors in the economy, as measured by x. In this section we analyze what happens when firms may get organized and exert their political power to induce the government to deviate from the efficient outcome in the attempt to obtain a more favorable value of δ.

We assume that firms in both sectors may decide to be active in the lobbying process and, following Grossman and Helpman's (1994) seminal paper, we model lobbying as a menu auction (Bernheim and Whinston, 1986) in which interest groups offer contingent payments to the policy-maker in order to influence his action.[18] Moreover, lobbying is endogenous, as in Baldwin and Robert-Nicoud (2007): each lobby may decide to offer

[18] This is the so-called influence motive for lobbying. Lobbies can be also motivated by electoral motives, i.e. they might try to influence a candidate's chance of winning the election (see Grossman and Helpman, 2001 for a discussion). In this case, lobbies' contributions would be used to "buy" the vote of impressionable

contributions to the government, which, simultaneously, decides whether to accept the contributions offered. The political equilibrium of this endogenous lobbying game represents the major novelty of our study. We also characterize the optimal mix of education at the equilibrium.

4.1 Lobbying

There are two organized groups, one representing firms in sector s, the other representing firms in sector f. Workers are politically not organized.[19] Lobbies offer political contributions to the government in order to influence its choice of the education mix and the government decides whether to accept them or not. We look at the conditions under which firms in each sector will find it convenient to invest in lobbying offering contributions to the government and the government, simultaneously, will decide whether to accept the contributions offered.

We indicate by $C_j(\delta)$ the payment offered by each firm in sector j contingent on the government choice of δ. Lobbying is costly: if the firm exerts lobby, it pays part of its profits as contributions to the government. We introduce two indicator functions: I, which can take only two values, $I_j = 1$ if sector j offers contingent payments and $I_j = 0$ if it does not, and G, which can take only two values, $G_j = 1$ if the government accepts the contribution offered by sector j and $G_j = 0$ if it does not accept it.[20] As in Grossman and Helpman (1994), contributions are restricted to be globally "truthful", [21] that is firms

citizens (cfr. Grossman and Helpman, 1996). In our model we do not consider elections and restrict the attention to post-electoral lobbying.

[19] We find qualitatevely similar results if also workers exert lobby.

[20] As in Baldwin and Robert-Nicoud (2007), in our model at equilibrium the government always accepts contributions. This is different from Felli and Merlo (2006), where the policymaker chooses the set of lobbies whom to bargain with excluding lobbies whose policy position is too close to its own.

[21] Bernheim and Winston (1996) show that if contribution functions are differentiable, they are locally truthful. They also show that equilibria based on truthful strategies not only exist but always result in an efficient choice of action. For situations in which non-binding communication is possible, these equilibria have a strong stability property, namely they are coalition-proof Nash. In other words, truthful equilibria are stable even if coalitions of players can communicate to devise a mutually preferable strategy.

offer payments that reflect their true willingness to pay, i.e., for $j = f, s$ it is:

$$\frac{\partial C_j(\delta)}{\partial \delta} = \frac{\partial \pi_j(\delta)}{\partial \delta}$$

Truthful contribution functions offered by each firm in sector j can thus be written as:

$$C_j(\delta) = \pi_j(\delta) - B_j \text{ if } I_j = 1; \text{ 0 otherwise} \tag{17}$$

where B_j are scalars which represents the reservation utility of the firm and will be determined in the appendix, while proving proposition 3.

Total lobby contributions can thus be expressed as follows:

$$C(\delta) = \gamma G_f I_f C_f(\delta) + (1-\gamma) G_s I_s C_s(\delta) \tag{18}$$

4.2 Different cases of active lobbying

To determine the political equilibrium with endogenous lobbying, we first have to derive the optimal mix of education in the different cases of active lobbying, i.e. when both sectors are active, or when just one of the two sectors exerts lobby.

Consider first the case in which both sectors are active in the lobbying process, i.e. $G_j = I_j = 1$ for $j = f, s$. The government's objective function reduces to:

$$\Omega = \Delta + a[\gamma C_f(\delta) + (1-\gamma) C_s(\delta)]$$

Recalling Eq.(7), the first order condition with respect to δ can thus be written as follows:

$$\frac{\partial \Omega(\delta)}{\partial \delta} = \frac{\partial W_f(\delta)}{\partial \delta} + \frac{\partial W_s(\delta)}{\partial \delta} + \frac{\partial \Pi_f(\delta)}{\partial \delta} + \frac{\partial \Pi_s(\delta)}{\partial \delta} + a\left[\gamma \frac{\partial \pi_f(\delta)}{\partial \delta} + (1-\gamma)\frac{\partial \pi_s(\delta)}{\partial \delta}\right] \tag{19}$$

$$= \frac{\partial W_f(\delta)}{\partial \delta} + \frac{\partial W_s(\delta)}{\partial \delta} + (1+a)\left[\frac{\partial \Pi_f(\delta)}{\partial \delta} + \frac{\partial \Pi_s(\delta)}{\partial \delta}\right] \tag{20}$$

This implies that the government behaves as if it were maximizing a weighted sum of workers wage (with weight equal to 1) and firms' profits (with weight $1 + a$). We can thus prove the following result.

Proposition 1 *When both sectors are active in the lobbying process, the equilibrium mix of education spending is the same as the one that would be chosen by the social planner ($\delta_{fs} = \delta_{PL} = \frac{1}{1+x}$).*

Intuitively, if the two lobbies have the same weight in the government's objective function, they lobby against each other and their political pressures exactly balance. Thus, proposition 1 suggests that a different weight between wages and profits in the government's objective function (i.e. the value of a) does not alter the composition of human capital as compared with what would be chosen by the social planner.

Suppose instead that only one sector is politically organized, for instance only the first sector exerts lobby. The government objective function becomes:

$$\Omega = W_f + W_s + \Pi_f + \Pi_s + a\gamma C_f \tag{21}$$

and the first order condition requires:

$$\frac{\partial \Omega(\delta)}{\partial \delta} = \frac{\partial W_f(\delta)}{\partial \delta} + \frac{\partial W_s(\delta)}{\partial \delta} + \frac{\partial \Pi_s(\delta)}{\partial \delta} + (1+a)\frac{\partial \Pi_f(\delta)}{\partial \delta} = 0 \tag{22}$$

Using Eq.(5), (4), (6), (7) and solving the first order condition, we obtain the following level of δ:

$$\delta_f = \frac{1}{1+\eta} \tag{23}$$

where $\eta = x\left(\frac{1}{1+a(1-\alpha)}\right)^{\frac{1}{1-\alpha}}$.

Similarly, if only the second sector lobbies, we obtain the following level of δ:

$$\delta_s = \frac{1}{1+\mu} \tag{24}$$

where $\mu = x\left[1+a(1-\alpha)\right]^{\frac{1}{1-\alpha}}$.

Defining $\sigma = \left[1+a(1-\alpha)\right]^{\frac{1}{1-\alpha}} > 1$, we can notice that $\eta = \frac{x}{\sigma}$ and $\mu = x\sigma$.

Thus, it is immediate to check that $\mu > x > \eta$ and thus $\delta_f > \delta_{PL} > \delta_s$. This proves the result reported in the next proposition.

Proposition 2 *When only the sector using the first (second) type of education exerts lobby, more resources are directed towards the first (second) type of education with respect to the social planner solution.*

The proposition delivers an intuitive result: when only one sector exerts lobby, it manages to attract more resources towards the type of education which is interesting for its production. With only one lobby, the weight given by government to contributions (a) affects the composition of human capital: the higher is a, the more the skill composition is twisted towards the lobby's favorite one.

4.3 Political equilibrium with endogenous lobbying

Il lobbying is endogenous, firms must decide whether (or not) it is worthwhile to set up a lobby and pay the contributions required to influence the government's education policy. A sector will get organized if profits, net of contributions, are higher if organized than if not.

Having in mind the results in the previous section, we can characterize the endogenous lobbying equilibrium.

Proposition 3 *Active lobbying by both sectors is a Nash equilibrium of the political lobbying game.*

Intuitively, if one sector sets up a lobby to influence the government's choice, then the other sector is better off by doing the same. At equilibrium both sectors will lobby and the optimal mix of education coincides with the one chosen by the social planner.

4.4 Political equilibrium with costly lobbying

The result of active lobbying by both sectors at equilibrium is however not the end of the story. Organizing a lobby is costly: on top of payments for the administrative structure, expenditures are required for "establishing links with politicians, hiring professional lobbyists, building a communications network among members, designing a scheme of punishments for defaulting members, etc" (see Mitra, 1999).

Assume that to get organized a group has to pay a cost $K > 0$ (equal for both sectors). In this case, an interest group may find it convenient to lobby only if its net benefit is larger than its cost. Having this in mind, and remembering that x is our global indicator of the "relative importance" of the two sectors, based on relative size, price and productivity, we can prove the following result.

Proposition 4 *If the two sectors have the same "relative importance" ($x = 1$), either firms in both sectors will exert lobby or none of them will do it. If the two sectors have a different relative importance ($x \neq 1$), there exists a level of K of the lobbying cost such that only firms in the "relatively more important" sector will find it convenient to exert lobby (i.e. firms in sector f when $x < 1$ and firms in sector s when $x > 1$).*

The above result suggests that the relative importance of the two sectors matters to determine firms' net benefits from lobbying and thus, given the fixed cost, the decision on whether or not to set up a lobby. When only one sector exerts lobby, the equilibrium mix of education is different from the one decided by the social planner and, as we proved in proposition 2, the sector exerting lobbying is able to direct education expenditure in favor of the type of education that is needed for its production.

Given the expression of x, a sector's relative importance depends on its share in total output, its relative productivity and relative price. Thus, the influence that a sector has on the economy's composition of human capital can be attributed to its size, its market structure (price), its share of value added and its relative productivity. A small sector open to competition and less exposed to technical progress for instance might find it difficult to get organized, due to the limited amount of profits that can be used to "bribe" the policymaker. Moreover, size itself is important in determining a sector's decision on whether or not to lobby; in fact, given the fixed cost to be paid to organize a lobby, per-firm cost will be lower the higher the number of firms. This is of course due to our assumption that the cost is fixed and in particular it does not depend on the number of firms belonging to a lobby.[22]

A natural interpretation of our results is given in case the two sectors differ for the type of technology adopted, low-technology and high-technology. In this case, proposition 4 suggests that, if the low-technology sector is the one which, due to its "relative importance", finds it convenient to exert lobby, it will also be able to direct public expenditure toward fields of education functional to a low-tech economy. Viceversa, if the

[22] The assumption of fixed cost may seem quite restrictive, as some organizational cost are likely to increase with the number of firms. However what matters here is that the cost in per capita terms decreases as the number of firms increases.

high-technology sector is the one that finds it convenient to exert lobby, an equilibrium will emerge in which the type of education functional to technical progress and growth will be favoured.

Two natural extensions are worth mentioning at this point. First, one may want to allow for heterogeneity in the fixed cost because groups may differ in their organizational abilities (see Mitra, 1999) or "proximity" to the government (see Faccio, 2006). Obviously, the sector that has a smaller K will, *ceteris paribus*, find it more convenient to exert lobby. Second, one may want to allow for heterogeneity in the weight attributed by the government to contributions paid by different groups. In both circumstances, even if the two sectors have the same importance ($x = 1$) it may be that only the sector "closer" to the government finds it convenient to get organized, and thus, to obtain that more resources are directed towards the type of education that it uses.

5 Concluding remarks

We have presented a two-sector political economy model in which individuals choose the type of education to acquire and the government's education policy affects this choice. In our setting, firms may lobby the policymaker in the attempt to obtain the desired supply of skill. Our purpose is to contribute to explain the observed differences in education systems and the relation between the composition of education and the structure of production.

As we know that lobbying activity is diffused in many countries (such as US and Canada) and that firms may lobby for education, we argue that a country's skill composition can be the result of lobbying activity by firms active in different sectors.

We have shown that, if organizing a lobby is costly, an equilibrium might emerge in which firms in the "stronger" sector are able to bribe the policymaker and twist its choice of the education mix towards the type of skill needed in their production. Thus, lobbying may induce persistence in an economy's output composition.

As we pointed out before, our model is quite general and can be used to analyze many real situations. One example would be the case of traditional (low-technology) versus technology-driven industries. If the traditional sector is "stronger", then our model predicts that, under the influence of lobbying, a country might be trapped in a low-skill and low-technology specialization. Next, consider a country that to face competition on the global market is planning to change its productive specialization. Suppose it wants to reduce the relative size of the financial sector and promote the so-called green economy. According to our result, if the financial sector, a top lobbyists in the US, is powerful enough, then, the status quo is likely to persist unless industrial policy is coordinated with education policy. To give yet another example, consider an established and relative sheltered sector vis-à-vis a new, highly innovative and potentially growing sector. Once again, without a proper policy (e.g. liberalization) or a shock that twists the balance of power in favor of the new sector, the status quo is bound to prevail.

An interesting application of the model would consider immigration policy. In this setting, the labor force consists of previously trained individuals and immigrants, i.e. individuals trained abroad. Our model would suggest that, under the influence of lobbying, countries specialized in high-tech sectors will favor the in-coming of highly qualified immigrants; on the contrary, countries with a structure of production mainly devoted to traditional sectors will be biased in favor of low-qualified immigrants.

A natural extension of our model would be to investigate into the causes which determine the relative importance of the two sectors x. In our framework, to move from one equilibrium to the other, an exogenous shock is needed. In a truly dynamic settings all the parameters influencing x should be endogenized. In particular, innovation might differentially influence productivity in the two sectors and thus would be a natural candidate as driving force for this dynamics. To move the equilibrium, technological progress would have to overcome the pressure for the status quo that comes from lobbying.

Our results also raise several crucial questions on the normative side: how can a country afford the challenge of globalization, if it does not attract talented individuals in fields of education which produce the skills needed in highly innovative and potentially growing sectors? [23]

[23] As explained by Parente and Prescott (2000) the protection of specialized groups of factor suppliers and corporate interests through constraints relating to the use of technology may even be detrimental for growth.

Finally, in terms of policy implications, we suggest that education policy and the structure of education together with industrial policy should be given top priorities in the governments' agenda, and the role of lobbying activities by firms should not be neglected. In particular, countries should carefully consider the lobbying activity exerted by traditional sectors with low-technology specialization and its consequences on the industrial structure and the overall economy.

6 Appendix

6.1 The social planner

Recalling the social planner's objective function:

$$\Delta = \gamma^{1-\alpha} A_f p_f \delta^{\alpha} + (1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha}$$

its maximization delivers the following first order condition

$$\alpha\gamma^{1-\alpha} A_f p_f \delta^{\alpha-1} - \alpha(1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha-1} = 0$$

which can be rewritten as

$$\left(\frac{\delta}{1-\delta}\right)^{\alpha-1} = \frac{(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}$$

and thus

$$\delta = \delta_{PL} = \frac{1}{1 + \left(\frac{A_s p_s}{A_f p_f}\right)^{\frac{1}{1-\alpha}} \left(\frac{1-\gamma}{\gamma}\right)} = \frac{1}{1+x}$$

which corresponds to Eq.(16). Notice that $\delta_{PL} \in (0,1)$.

6.2 Proof of proposition 1

The equilibrium level of δ is given by solving the following first order condition:

$$\frac{\partial \Omega}{\partial \delta} = \alpha\gamma^{1-\alpha} A_f p_f \delta^{\alpha-1} + \alpha(1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha-1} + (1+a)(1-\alpha)[\gamma^{1-\alpha} A_f p_f \delta^{\alpha-1} + (1-\gamma)^{1-\alpha} A_s p_s (1-\delta)^{\alpha-1}] = 0$$

which delivers the same level δ_{PL} chosen by the social planner at Eq. (16).

6.3 Proof of proposition 3

To show that lobbying by both sectors is a Nash equilibrium, we have to check that if one sector lobbies then the other is better off by doing the same. We proceed in two steps: (i) compute the scalars B_s and B_f (ii) show that if firms in sector $f(s)$ are lobbying, then firms in sector $s(f)$ are better off by paying the contributions and have δ_{PL} rather than paying no contribution and having the level of δ that would be chosen if only the other sector would lobby.

(i) Computation of B_s and B_f

To compute B_s, consider the case where only firms in the first sector exert lobby. In this case we know that the equilibrium mix of education spending is given by Eq.(23) with $\delta_f > \delta_{PL}$. If firms in sector f pay contributions and the government accepts them, the government's objective function is:

$$\Omega(\delta_f) = \Delta(\delta_f) + a\gamma C_f(\delta_f) = \Delta(\delta_f) + a[\Pi_f(\delta_f) - \gamma B_f] \tag{25}$$

On the other hand, if both sectors exert lobby, then $\delta = \delta_{PL}$. In this case the government objective function is:

$$\Omega(\delta_{PL}) = \Delta(\delta_{PL})+a[\gamma C_f(\delta_{PL})+(1-\gamma)C_s(\delta_{PL})] = \Delta(\delta_{PL})+a[\Pi_f(\delta_{PL})-\gamma B_f+\Pi_s(\delta_{PL})-(1-\gamma)B_s]$$

Thus, to induce the government to accept its contributions, sector s should leave the government at least indifferent between $\Omega(\delta_f)$ and $\Omega(\delta_{PL})$ which requires

$$B_s = \frac{\Delta(\delta_{PL}) - \Delta(\delta_f) + a\left[\Pi_f(\delta_{PL}) - \Pi_f(\delta_f)\right] + a\Pi_s(\delta_{PL})}{a(1-\gamma)} \tag{26}$$

Each firm in sector s will find it convenient to pay the contributions only if $\pi_s(\delta_{PL}) - C_s(\delta_{PL}) = B_s > \pi_s(\delta_f)$ i.e. if

$$a(1-\gamma)\left[B_s - \pi_s(\delta_f)\right] = \Delta(\delta_{PL}) - \Delta(\delta_f) + a\left[\Pi_f(\delta_{PL}) - \Pi_f(\delta_f)\right] + a\Pi_s(\delta_{PL}) - a\Pi_s(\delta_f) > 0 \tag{27}$$

Similarly, we can compute

$$B_f = \frac{\Delta(\delta_{PL}) - \Delta(\delta_s) + a\left[\Pi_s(\delta_{PL}) - \Pi_s(\delta_s)\right] + a\Pi_f(\delta_{PL})}{a\gamma}$$

Each firm in sector f will find it convenient to pay the contributions only if $\pi_f(\delta_{PL}) - C_f(\delta_{PL}) = B_f > \pi_f(\delta_s)$ i.e. if

$$a\gamma\left[B_f - \pi_f(\delta_s)\right] = \Delta(\delta_{PL}) - \Delta(\delta_s) + a\left[\Pi_s(\delta_{PL}) - \Pi_s(\delta_s)\right] + a\Pi_f(\delta_{PL}) - a\Pi_f(\delta_s) > 0 \quad (28)$$

If the above conditions are satisfied, then, if sector $f(s)$ lobbies then sector $s(f)$ is better off by doing the same.

(ii) We now show that the above conditions for a Nash equilibrium are satisfied

Introducing the following generic expression for δ:

$$\delta = \frac{1}{(1+d)} \quad (29)$$

(where $d = x$ if $\delta = \delta_{PL}$; $d = \eta$ if $\delta = \delta_f$; $d = \mu$ if $\delta = \delta_s$)

we can rewrite the government objective function at Eq. (15) as

$$\Delta(\delta) = \gamma^{1-\alpha} A_f p_f \left(\frac{1}{1+d}\right)^{\alpha} \left[1 + \frac{d^{\alpha}(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}\right] \quad (30)$$

Using Eq. (29) into (6) and (7) we can also rewrite profits in the two sectors as:

$$\Pi_f(d) = \gamma^{1-\alpha}(1-\alpha) A_f p_f \left(\frac{1}{1+d}\right)^{\alpha} \quad (31)$$

and

$$\Pi_s(d) = (1-\gamma)^{1-\alpha}(1-\alpha) A_s p_s \left(\frac{d}{1+d}\right)^{\alpha} \quad (32)$$

Using Eq. (26), (5), (4), (6), (7) and choosing the appropriate value of d in each case, Eq. (27) becomes:

$$\begin{aligned} & \left(\frac{1}{1+x}\right)^{\alpha} \left[\gamma^{1-\alpha} A_f p_f + (1-\gamma)^{1-\alpha} A_s p_s x^{\alpha}\right] - \\ & \left(\frac{1}{1+\eta}\right)^{\alpha} \left[\gamma^{1-\alpha} A_f p_f + (1-\gamma)^{1-\alpha} A_s p_s \eta^{\alpha}\right] + \\ & a\left[\gamma^{1-\alpha}(1-\alpha)\left(\frac{1}{1+x}\right)^{\alpha} A_f p_f - \gamma^{1-\alpha}(1-\alpha)\left(\frac{1}{1+\eta}\right)^{\alpha} A_f p_f\right] + \\ & a\left[(1-\gamma)^{1-\alpha}(1-\alpha)\left(\frac{x}{1+x}\right)^{\alpha} A_s p_s - (1-\gamma)^{1-\alpha}(1-\alpha)\left(\frac{\eta}{1+\eta}\right)^{\alpha} A_s p_s\right] \\ > \; & 0 \end{aligned}$$

which, after some algebra con be rewritten as

$$\left[1 + a(1-\alpha)\right]\gamma^{1-\alpha} A_f p_f \left[\left(\frac{1}{1+x}\right)^{\alpha}\left(1 + \frac{x^{\alpha}(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}\right) - \left(\frac{1}{1+\eta}\right)^{\alpha}\left(1 + \frac{\eta^{\alpha}(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}\right)\right]$$

and, using the expression at Eq. (30), as

$$[1 + a(1-\alpha)]\,[\Delta(\delta_{PL}) - \Delta(\delta_f)] > 0$$

which is clearly satisfied given that the function $\Delta(\delta)$ reaches its maximum at $\delta = \delta_{PL}$.

Similarly, we can easily check that $B_f - \pi_f(\delta_s) = [1 + a(1-\alpha)]\,[\Delta(\delta_{PL}) - \Delta(\delta s)] > 0$. Q.E.D.

6.4 Proof of proposition 4

Remember that

$$a(1-\gamma)\,[B_s - \pi_s(\delta_f)] = [1 + a(1-\alpha)]\,[\Delta(\delta_{PL}) - \Delta(\delta_f)]$$

and

$$a\gamma\,[B_f - \pi_f(\delta_s)] = [1 + a(1-\alpha)]\,[\Delta(\delta_{PL}) - \Delta(\delta_s)]$$

Given the (total) cost (K) of organizing a lobby, firms in sector f will lobby if $B_f - \pi_f(\delta_s) > \frac{K}{\gamma}$ and firms in sector s if $B_s - \pi_s(\delta_f) > \frac{K}{(1-\gamma)}$. Thus, using the above expressions, if $\Delta(\delta_f) = \Delta(\delta_s)$ either firms in sector f and firms in sector s all exert lobby, or none of them do it; if $\Delta(\delta_f) < \Delta(\delta_s)$ then there exists a level of K such that only firms in sector s exert lobby; finally, if $\Delta(\delta_f) > \Delta(\delta_s)$ then there exists a level of K such that only firms in sector f exert lobby. To compare $\Delta(\delta_f)$ and $\Delta(\delta_s)$ we use Eq. (30), i.e.

$$\Delta(\delta_f) = \gamma^{1-\alpha} A_f p_f \left(\frac{1}{1+\eta}\right)^{\alpha} \left[1 + \frac{\eta^{\alpha}(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}\right] \tag{33}$$

and

$$\Delta(\delta_s) = \gamma^{1-\alpha} A_f p_f \left(\frac{1}{1+\mu}\right)^{\alpha} \left[1 + \frac{\mu^{\alpha}(1-\gamma)^{1-\alpha} A_s p_s}{\gamma^{1-\alpha} A_f p_f}\right] \tag{34}$$

which, using $x = \frac{1-\gamma}{\gamma}\left(\frac{A_s p_s}{A_f p_f},\right)^{\frac{1}{1-\alpha}}$ can be rewritten as:

$$\Delta(\delta_f) = \gamma^{1-\alpha} A_f p_f \left(\frac{1}{1+\eta}\right)^{\alpha} \left[1 + \eta^{\alpha} x^{1-\alpha}\right] \tag{35}$$

and

$$\Delta(\delta_s) = \gamma^{1-\alpha} A_f p_f \left(\frac{1}{1+\mu}\right)^{\alpha} \left[1 + \mu^{\alpha} x^{1-\alpha}\right] \tag{36}$$

Thus, we have that:

(i) $\Delta(\delta_f) = \Delta(\delta_s)$ if $\left(\frac{1}{1+\eta}\right)^{\alpha}(1+\eta^{\alpha}x^{1-\alpha}) = \left(\frac{1}{1+\mu}\right)^{\alpha}(1+\mu^{\alpha}x^{1-\alpha})$. In this case either firms in both sectors lobby or none of them

(ii) $\Delta(\delta_f) > \Delta(\delta_s)$ if $\left(\frac{1}{1+\eta}\right)^{\alpha}(1+\eta^{\alpha}x^{1-\alpha}) > \left(\frac{1}{1+\mu}\right)^{\alpha}(1+\mu^{\alpha}x^{1-\alpha})$ In this case there exists a level of K such that only firms in sector f lobby

(iii) $\Delta(\delta_f) < \Delta(\delta_s)$ if $\left(\frac{1}{1+\eta}\right)^{\alpha}(1+\eta^{\alpha}x^{1-\alpha}) < \left(\frac{1}{1+\mu}\right)^{\alpha}(1+\mu^{\alpha}x^{1-\alpha})$ In this case there exists a level of K such that only firms in sector s lobby

Notice that, using $\eta = \frac{x}{\sigma}$ and $\mu = x\sigma$ we have that

$$\left(\frac{1}{1+\eta}\right)^{\alpha}(1+\eta^{\alpha}x^{1-\alpha}) = \frac{\sigma^{\alpha}+x}{(x+\sigma)^{\alpha}}$$

and

$$\left(\frac{1}{1+\mu}\right)^{\alpha}(1+\mu^{\alpha}x^{1-\alpha}) = \frac{1+\sigma^{\alpha}x}{(1+x\sigma)^{\alpha}}$$

where, as we know, $\alpha < 1$ and $\sigma = [1+a(1-\alpha)]^{\frac{1}{1-\alpha}} > 1$.

We thus have to compare the following two functions:

$$f(x) = \frac{\sigma^{\alpha}+x}{(x+\sigma)^{\alpha}}$$

and

$$g(x) = \frac{1+\sigma^{\alpha}x}{(1+x\sigma)^{\alpha}}$$

The three cases to be proved are thus:

(i) for $x = 1$, $f(x) = g(x)$ and thus $\Delta(\delta_f) = \Delta(\delta_s)$, i.e. either firms in both sectors lobby or none of them

(ii) for $x\epsilon(0,1)$, $f(x) > g(x)$ and thus $\Delta(\delta_f) > \Delta(\delta_s)$, i.e. there exists a level of K such that only firms in sector f lobby

(iii) for $x > 1$, $f(x) < g(x)$ and thus $\Delta(\delta_f) < \Delta(\delta_s)$ i.e. there exists a level of K such that only firms in sector s lobby

Result (i) is straightforward. For $x = 1$ we have that $f(1) = g(1) = \frac{1+\sigma^{\alpha}}{(1+\sigma)^{\alpha}}$.

To prove results (ii) and (iii) we proceed in 5 steps.

STEP 1 It is sufficient to prove (ii), i.e. if $f(x) > g(x)$ for $x\epsilon(0,1)$ then $f(x) < g(x)$for $x > 1$,i.e. (iii) is satisfied.

This is because we can easily check that $f(\frac{1}{x}) - g(\frac{1}{x}) = x^{1-\alpha}\left[g(x) - f(x)\right]$. Thus, if for $x < 1$, $f(x) > g(x)$ we have that $f(\frac{1}{x}) < g(\frac{1}{x})$ which means that $f(y) < g(y)$ for any $y > 1$.

Thus, in what follows we restrict to $x\epsilon[0,1]$

STEP 2 $f(x)$ is increasing and concave.

We first calculate $f'(x)$:

$$f'(x) = \frac{(\sigma + x) - \alpha(\sigma^{\alpha} + x)}{(\sigma + x)^{\alpha+1}} \tag{37}$$

which is always positive for $\alpha < 1$ and $\sigma > 1$.

The second derivative of $f(x)$ with respect to x can be written as follows:

$$f''(x) = \frac{(1-\alpha)(\sigma + x)^{\alpha+1} - (\alpha+1)(\sigma+x)^{\alpha}\left[x(1-\alpha) + (\sigma - \alpha\sigma^{\alpha})\right]}{(x+\sigma)^{2\alpha+2}}$$

which, after simple algebra, becomes

$$f''(x) = \frac{-\alpha x(1-\alpha) - \alpha\sigma\left[2 - \sigma^{\alpha-1}(1-\alpha)\right]}{(x+\sigma)^{\alpha+2}}$$

which is negative given that $2 - \sigma^{\alpha-1}(1-\alpha) > 0$ for $\sigma > 1$ and $\alpha < 1$.

Notice that having $f(x)$ always increasing implies that $f(1) = g(1) = \frac{1+\sigma^{\alpha}}{(1+\sigma)^{\alpha}} > f(0) = g(0) = 1$

STEP 3 Function $g(x)$ is either always increasing (if $\sigma^{\alpha} > \alpha\sigma$), or it has a minimum at $\overline{x} = \frac{\alpha\sigma - \sigma^{\alpha}}{\sigma^{\alpha+1}(1-\alpha)}$ (if $\sigma^{\alpha} < \alpha\sigma$).

We first calculate $g'(x)$:

$$g'(x) = \frac{\sigma^{\alpha}(1 + \sigma x) - \alpha\sigma(1 + \sigma^{\alpha}x)}{(1+\sigma x)^{\alpha+1}} \tag{38}$$

which delivers the result at step 3.

STEP 4 $g(x)$ is concave for $x > \widehat{x} = \frac{\alpha+1-2\sigma^{\alpha-1}}{\sigma^{\alpha}(1-\alpha)}$ and convex for $x < \widehat{x}$ with $\overline{x} < \widehat{x} < 1$.

The second derivative of $g(x)$ with respect to x can be written as follows:

$$g''(x) = \frac{\sigma^{\alpha+1}(1-\alpha)(1+\sigma x)^{\alpha+1} - \sigma(\alpha+1)(1+\sigma x)^{\alpha}\left[\sigma^{\alpha+1}x(1-\alpha) + \sigma^{\alpha} - \alpha\sigma\right]}{(1+\sigma x)^{2\alpha+2}}$$

which, after simple algebra, becomes:

$$g''(x) = \frac{-(1-\alpha)\sigma^{\alpha+1}x - 2\sigma^{\alpha} + (\alpha+1)\sigma}{(1+\sigma x)^{\alpha+2}}\alpha\sigma$$

which is equal to zero at $x = \widehat{x}$, it is positive for $x < \widehat{x}$ and negative for $x > \widehat{x}$.

Again, given that $\alpha < 1$ and $\sigma > 1$ it is easy to check that $\overline{x} < \widehat{x} < 1$.

STEP 5 $f'(0) > g'(0)$ and $f'(1) < g'(1)$.

This result can be more easily shown starting from the following equivalence:

$$\frac{\partial}{\partial x} \log f(x) = \frac{f'(x)}{f(x)}$$

where $f'(x) = \frac{\partial}{\partial x} f(x)$. Thus

$$\begin{aligned} f'(x) &= f(x)\frac{\partial}{\partial x} \log f(x) = f(x)\frac{\partial}{\partial x}\left[\log(x+\sigma^\alpha) - \alpha\log(x+\sigma)\right] = \\ & f(x)\left[\frac{1}{x+\sigma^\alpha} - \frac{\alpha}{x+\sigma}\right] \end{aligned} \tag{39}$$

and

$$\begin{aligned} g'(x) &= g(x)\frac{\partial}{\partial x} \log g(x) = g(x)\frac{\partial}{\partial x}\left[\log(1+\sigma^\alpha x) - \alpha\log(1+\sigma x)\right] = \\ & g(x)\left[\frac{\sigma^\alpha}{1+\sigma^\alpha x} - \frac{\alpha\sigma}{1+\sigma x}\right] \end{aligned} \tag{40}$$

Evaluating f' at Eq.(37) and g' at Eq. (38) at $x = 0$ we have that

$$\begin{aligned} f'(0) &= f(0)\left[\frac{1}{\sigma^\alpha} - \frac{\alpha}{\sigma}\right] = \left[\frac{1}{\sigma^\alpha} - \frac{\alpha}{\sigma}\right] \\ g'(0) &= g(0)\left[\sigma^\alpha - \alpha\sigma\right] = \left[\sigma^\alpha - \alpha\sigma\right] \end{aligned}$$

For $\sigma^\alpha < \alpha\sigma$, $g'(0) < 0$ and thus $g'(0) < 0 < f'(0)$.For $\sigma^\alpha > \alpha\sigma$, we can prove, using Mathematica, that$\frac{f'(0)}{g'(0)} = \frac{\left[\frac{1}{\sigma^\alpha} - \frac{\alpha}{\sigma}\right]}{\left[\sigma^\alpha - \alpha\sigma\right]} > 1$ for any value of the parameters α, σ.

Evaluating f' at Eq.(37) and g' at Eq. (38) at $x = 1$ we have that

$$\begin{aligned} f'(1) &= f(1)\left[\frac{1}{1+\sigma^\alpha} - \frac{\alpha}{1+\sigma}\right] \\ g'(1) &= g(1)\left[\frac{\sigma^\alpha}{1+\sigma^\alpha} - \frac{\alpha\sigma}{1+\sigma}\right] \end{aligned}$$

Using $f(1) = g(1) = \frac{1+\sigma^\alpha}{(1+\sigma)^\alpha}$ after simple algebra we can write

$$\frac{g'(1)}{f'(1)} = \frac{\sigma^\alpha(1+\sigma) - \alpha\sigma(1+\sigma^\alpha)}{1+\sigma-\alpha(1+\sigma^\alpha)}$$

which, using Mathematica can be proved to be always greater than 1 for any value of the parameters α, σ.

To sum up, we have considered the two functions f and g, which reach the same value at $x = 0$ and $x = 1$. In the interval $(0, 1)$ function f is always increasing and concave, function g may either be always increasing or first decreasing and then increasing. However, given that at $x = 0$ function f has a derivative higher than function g, function f starts above function g. Since they never cross again before $x = 1$, function f remains above function g till $x = 1$. Given that at $x = 1$ instead function g has a higher derivative than f and both are concave at that point, function g crosses function f at $x = 1$. We have also proved that having f above g for the interval $(0, 1)$ also implies that f is below g for $x > 1$. Q.E.D.

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Table 1: Expenditure in education

	Expenditures in education as % of GDP				Total expenditures per student US$PPP (a)	Graduates in upper secondary general programmes (b)	Graduation rate Tertiary-type A programmes (first degree)
	Primary, secondary and post-secondary non-tertiary education	Tertiary education	Total (public and private) all level of education	Total (public) all level of education			
Australia	3,5	1,5	5,2	3,8	8.786	62,6	59,2
Austria	3,6	1,3	5,4	5,1	10.974	18,6	25,0
Belgium	4,1	1,3	6,1	5,9	9.162	34,4	27,8
Canada	3,5	2,6	6,1	4,6	m	90,7	40,0
Czech Republic	2,8	1,2	4,6	4,1	5.426	24,7	37,3
Denmark	4,3	1,7	7,1	6,6	10.759	53,3	46,5
Finland	3,6	1,6	5,6	5,5	8.440	35,6	82,0
France	3,9	1,4	6,0	5,5	8.932	45,2	35,4
Germany	3,0	1,1	4,7	4,0	8.270	42,7	25,5
Greece	m	m	m	m	m	68,8	23,6
Hungary	3,2	0,9	4,9	4,9	4.811	79,8	34,3
Iceland	5,1	1,2	7,8	7,0	9.015	54,3	57,4
Ireland	3,48	1,2	4,7	4,4	8.628	55,9	46,1
Italy	3,1	0,9	4,5	4,1	7.948	34,6	32,8
Japan	2,8	1,5	4,9	3,3	9.312	75,6	39,4
Korea	4,0	2,4	7,0	4,2	7.325	72,7	43,4
Luxembourg	3,1	m	m	m	m	38,8	5,3
Mexico	3,8	1,2	5,7	4,7	2.598	92,2	18,1
Netherlands	3,7	1,5	5,6	4,7	9.883	34,6	44,7
New Zealand	4,0	1,5	5,9	4,8	6.226	m	50,7
Norway	3,7	1,3	5,5	5,4	11.967	59,6	44,9
Poland	3,4	1,3	5,3	4,8	4.134	62,3	50,0
Portugal	3,5	1,6	5,6	5,1	6.677	67,6	45,3
Slovak Republic	2,5	0,9	4,0	3,4	3.694	25,7	57,1
Spain	2,9	1,1	4,8	4,2	8.618	53,9	29,8
Sweden	4,1	1,6	6,3	6,1	10.262	43,5	39,2
Switzerland	4,0	1,2	5,5	5,1	13.031	30,4	30,4
Turkey	m	m	m	m	m	66,4	19,7
United Kingdom	4,2	1,3	5,8	5,2	9.600	100,0	40,1
United States	4,0	3,1	7,6	5,0	14.269	100,0	37,3

(a) Public institution only for Hungary, Poland, Portugal, Switzerland and Italy (except in tertiary education).

(b) For United Kingdom and United States, year of reference is 2006.

Expenditures on Education as % of GDP (year 2007): Education at Glance, 2010.

Expenditures per student US$PPP based on full-time equivalents (year 2007): Education at Glance, 2010.

Graduates in upper secondary general programmes (year 2008): Oecd.stat - Education and training

Graduation rate (year 2008): Education at a Glance, 2010

Table 2. Tertiary education

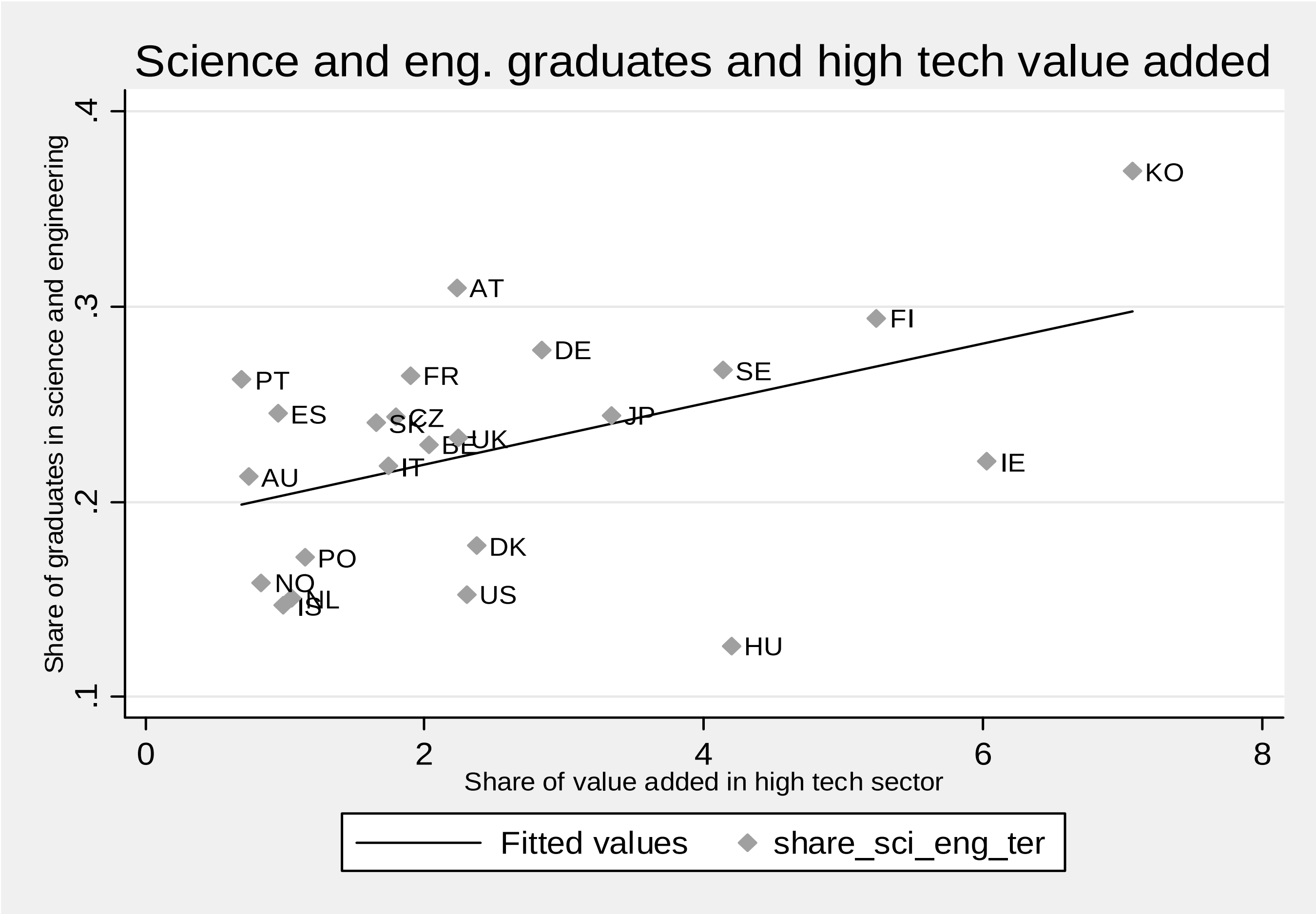
	Tertiary-type A and advanced research programmes (2008)							
	Shares over all fields of study							
	Education	Humanities and Arts	Social sciences business and law	Science	Engineering manufacturing and construction	Agriculture	Health and welfare	Services
Australia	0,11	0,11	0,43	0,12	0,07	0,01	0,15	0,03
Austria	0,11	0,10	0,39	0,13	0,14	0,01	0,10	0,02
Belgium	0,05	0,17	0,36	0,07	0,13	0,03	0,16	0,01
Canada	0,11	0,13	0,37	0,13	0,08	0,01	0,10	0,03
Czech Republic	0,16	0,07	0,32	0,10	0,17	0,04	0,07	0,04
Denmark	0,09	0,15	0,28	0,08	0,12	0,01	0,26	0,01
Finland	0,08	0,17	0,26	0,12	0,15	0,02	0,15	0,05
France	0,02	0,14	0,42	0,14	0,13	0,01	0,10	0,04
Germany	0,09	0,22	0,27	0,16	0,12	0,01	0,09	0,02
Greece	0,12	0,18	0,32	0,14	0,12	0,03	0,08	0,01
Hungary	0,19	0,09	0,39	0,06	0,08	0,02	0,10	0,08
Iceland	0,21	0,10	0,39	0,06	0,07	0,00	0,15	0,02
Ireland	0,09	0,20	0,34	0,13	0,08	0,01	0,14	0,01
Italy	0,06	0,16	0,36	0,07	0,15	0,02	0,15	0,03
Japan	0,06	0,17	0,35	0,05	0,19	0,03	0,08	0,02
Korea	0,10	0,19	0,23	0,10	0,23	0,02	0,09	0,04
Luxembourg	0,00	0,15	0,48	0,29	0,04	0,00	0,00	0,02
Mexico	0,14	0,04	0,42	0,10	0,14	0,02	0,10	0,03
Netherlands	0,15	0,09	0,37	0,06	0,08	0,01	0,18	0,05
New Zealand	0,14	0,16	0,40	0,13	0,07	0,01	0,17	0,01
Norway	0,18	0,09	0,29	0,08	0,08	0,01	0,24	0,05
Poland	0,17	0,08	0,43	0,08	0,09	0,02	0,09	0,05
Portugal	0,09	0,10	0,32	0,15	0,22	0,03	0,21	0,07
Slovak Republic	0,17	0,06	0,31	0,08	0,13	0,02	0,17	0,05
Spain	0,15	0,09	0,29	0,10	0,14	0,02	0,16	0,05
Sweden	0,21	0,06	0,24	0,07	0,17	0,01	0,27	0,01
Switzerland	0,12	0,13	0,37	0,12	0,12	0,01	0,10	0,02
Turkey	0,24	0,06	0,41	0,09	0,09	0,03	0,06	0,02
United Kingdom	0,10	0,18	0,34	0,14	0,09	0,01	0,14	0,01
United States	0,12	0,16	0,40	0,09	0,06	0,01	0,11	0,06

Table 3. Value added by sectors of production

Value added shares relative to total economy.	**TOTAL**											
	AGRICULTURE HUNTING, FORESTRY AND FISHING	MINING AND QUARRYING	MANUFAC TURING	ELECTRICITY GAS AND WATER SUPPLY	CONSTRUC TION	WHOLESALE AND RETAIL TRADE - RESTAURANT S AND HOTELS	TRANSPORT, STORAGE AND COMMUNIC ATIONS	FINANCE, INSURANCE REAL ESTATE AND BUSINESS SERVICES	COMMUNITY SOCIAL AND PERSONAL SERVICES	TOTAL SERVICES	HITECH High-technology manufactures	HMHTECH High and medium-high technology manufactures
Australia	2,3	7,8	11,2	2,3	7,4	13,1	7,7	29,6	18,6	69,0	0,7	3,1
Austria	1,7	0,5	20,0	2,4	6,9	17,3	6,2	24,3	20,8	68,6	2,2	8,4
Belgio	0,9	0,1	16,7	2,2	5,1	14,5	8,4	28,8	23,4	75,1	2,0	6,9
Czech Republic	2,6	1,3	26,3	4,3	6,3	14,9	10,7	16,4	17,3	59,2	1,8	11,1
Denmark	1,3	4,1	14,2	2,1	5,7	14,1	7,7	24,2	26,6	72,5	2,4	6,2
Finland	2,7	0,4	23,7	2,3	6,0	12,0	10,1	20,8	22,1	64,9	5,2	10,8
France	2,1	0,0	12,8	1,7	6,0	12,6	6,4	33,7	24,9	77,5	1,9	5,3
Germany	0,9	0,2	23,4	2,4	3,9	11,7	5,8	29,2	22,4	69,2	2,8	13,4
Greece	3,9	0,5	10,2	2,6	6,7	24,2	9,4	18,6	23,9	76,1	0,5	1,9
Hungary	4,1	0,2	22,5	2,6	4,8	13,1	7,7	22,3	22,8	65,9	4,2	11,9
Iceland	6,3	0,0	10,9	3,9	11,3	11,5	6,3	26,0	23,7	67,5	1,0	2,0
Ireland	1,6	0,5	22,1	1,2	10,2	13,1	5,3	27,7	18,3	64,4	6,0	12,8
Italy	2,1	0,4	18,7	2,1	6,1	15,3	7,4	26,9	21,0	70,7	1,7	6,9
Japan	1,4	0,1	20,7	3,2	6,1	17,0	6,4	26,7	18,4	68,5	3,3	10,6
Korea	3,3	0,3	28,0	2,3	9,0	9,8	7,1	21,2	19,0	57,1	7,1	16,2
Luxembourg	0,4	0,1	8,7	1,2	5,8	11,0	8,7	48,5	15,6	83,9	..	1,6
Netherlands	2,2	3,3	13,9	1,9	5,5	14,8	7,1	27,7	23,6	73,2	1,1	5,3
New Zealand	5,4	1,3	14,5	2,8	5,5	14,6	7,2	29,9	18,9	70,6	..	..
Norway	1,5	27,8	10,0	2,6	4,5	9,5	7,5	17,0	19,7	53,7	0,8	..
Poland	4,3	2,4	18,8	3,5	6,4	20,1	7,4	18,3	18,9	64,6	1,1	6,0
Portugal	2,8	0,0	14,8	2,9	6,6	17,3	7,0	22,0	26,5	72,9	0,7	3,2
Slovak Republic	3,6	0,4	24,1	6,8	7,7	16,7	7,2	17,6	15,9	57,4	1,6	8,2
Spain	2,8	0,3	15,5	2,0	12,1	18,0	6,9	21,7	20,8	67,4	0,9	5,2
Sweden	1,4	0,6	19,7	2,8	4,7	12,6	7,3	25,4	25,3	70,6	4,1	10,3
Switzerland	1,2	0,2	19,8	2,0	5,6	15,5	6,4	29,4	19,9	71,2	..	11,6
United Kingdom	0,7	2,7	13,0	1,6	6,3	14,4	6,9	31,0	23,4	75,7	2,2	5,5
United States	0,9	2,0	13,0	2,1	4,9	15,2	5,9	32,5	23,6	77,1	2,3	5,6

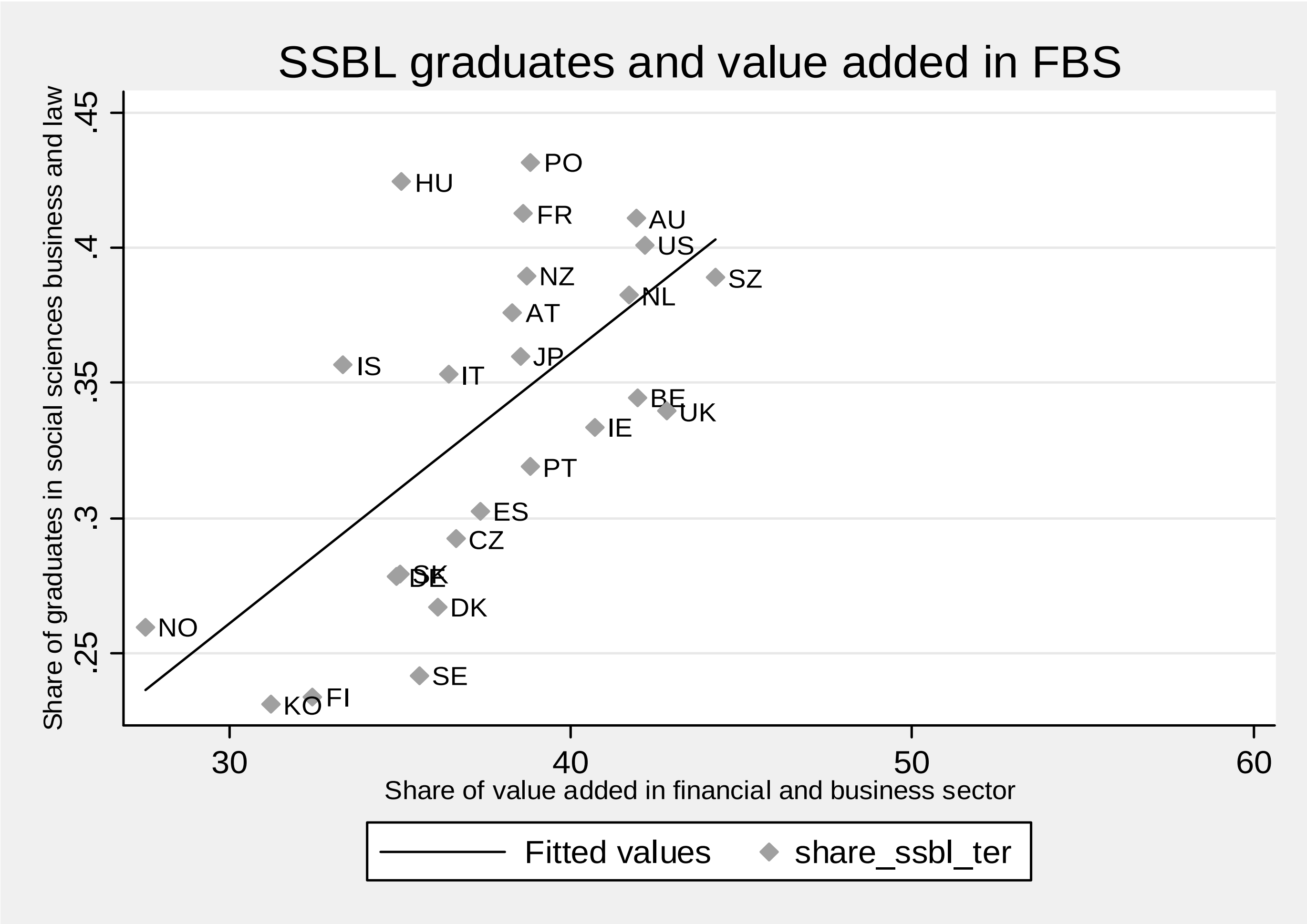
Source: OECD Stan Indicators 2009

Figure 1: Graduates in science and engineering and value added in high tech



Corr. 0.46; R2=0.21

Figure 2: Graduates in social science, business and law and value added in finance and business services



Corr. 0.63 ; R2=0.40