Growth and the Financing and Governance of Education*

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1 Introduction

A first look at the US versus the EU in 1999-2000 shows that 37.3% of the U.S. population aged 25-64 have completed a higher education degree, against only 23.8% of the EU population. This educational attainment comparison is mirrored by that on tertiary education expenditure, with the US devoting 3% of its GDP to tertiary education versus only 1.4% in the EU. Is this European deficit in tertiary education investment a big deal for growth?

Also, there are marked differences between the ownerrship structure and governance of American universities versus European universities and between European universities. Do these matter for research performance and for the contribution of these universities to the growth process?

In this lecture, we develop a framework to try and shed light on these questions. A first class of models emphasizes (physical or human) capital accumulation as the main source of growth. There, the neo-classical reference is Mankiw-Romer-Weil (1992) [MRW], and the AK reference is the celebrated article by Lucas (1988). In MRW, which is an augmented version of the Solow model with human capital as an additional accumulating factor of production, human capital accumulation slows down the convergence to the steady-state by counteracting the effects of decreasing returns to physical capital accumulation. In Lucas, instead, the assumption that human capital accumulates at a speed proportional to the existing stock of human capital, leads a positive long-run growth rate. Whether on the transition path to the steady-state (in MRW) or in steady-state (in Lucas), the rate of growth depends upon the rate of accumulation of human capital, not upon the stock of human capital. Moreover, these capital accumulation-based models do not distinguish between primary/secondary and tertiary education: the two are perfect substitutes in these models.

However Benhabib and Spiegel (1994) showed, based on cross-country regressions over the 1965-1985 period, that human capital accumulation (where human capital is measured by school enrollment) was not significantly correlated

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with growth, whereas human capital stocks were. Another source of scepticism towards the Lucas-MRW approach is the finding by Ha and Howitt (2005) that the trend growth rate of the number of R&D workers in the US has gone down over past 50 years, whereas the trend rate of productivity growth has not. In this lecture we consider an alternative approach to education and growth. Pioneered by Nelson and Phelps (1966), this approach emphasized the complementarity between human capital stocks on the one hand, and the process of innovation and technological catch-up on the other hand.

The lecture is organized as follows. In Section 2 we present the Nelson-Phelps model. In Section 3, we develop a model of appropriate education system to analyze the relationship between growth, the composition of education spending, and a country's level of technoogical development. In Section 4, we discuss evidence in support to our model. In Section 5, we analyze the relationship between the performance and governance of universities. Section 6 concludes.

2 Nelson-Phelps

More than just questioning the capital accumulation approach to education and growth, Benhabib and Spiegel (1994) resurrected the simple model by Nelson and Phelps (1966). Nelson and Phelps did not have a model of endogenous growth with endogenous R&D and innovation, but they were already thinking of growth as being generated by productivity-improving adaptations, whose arrival rate would depend upon the stock of human capital. More formally, Nelson and Phelps would picture a world economy in which, in any given country, productivity grows according to an equation of the form:

$$\dot{A} = f(h)(\overline{A} - A),$$

where again $\overline{A}$ denotes the frontier technology (itself growing over time at some exogenous rate), and h is the current stock of human capital in the country. A higher stock of human capital would thus foster growth by making it easier for a country to catch up with the frontier technology. Benhabib and Spiegel tested a slightly augmented version of the Nelson-Phelps in which human capital does not only facilitate the adaptation to more advanced technologies, by also makes it easier to innovate at the frontier, according to a dynamic equation of the form:

$$\dot{A} = f(h)(\overline{A} - A) + g(h)\gamma A,$$

where the second term capture the innovation component of growth.

Using cross country-regressions of the increase in the log of per capita GDP over the period 1965-1985 as a linear function of the sum of logs of human capital stocks over all the years between 1965 and 1985, Benhabib and Spiegel found a significantly positive correlation between the two, which in turn was evidence that the rate of productivity growth is also positively correlated with the stock of human capital. Moreover, BS found a larger correlation for countries further below the world technology frontier, which would hint at the catch-up component of growth being the dominant one. Thus, more than the rate of human capital accumulation, it is its stock that matters for growth. Does this help us understand the comparison between Europe and the US?

Unfortunately, more recent work by Krueger and Lindahl (2001) would temper our optimism. Using panel data over 110 countries between 1960 and 1990, choosing the number of years in education instead of the logarithm of that number to measure human capital[1], and correcting for measurement errors, Krueger and Lindahl would still find a positive correlation between growth and human capital stocks (although they also found a positive correlation between growth and the rate of accumulation of human capital), however the significance of the correlation between growth and human capital stocks would disappear when restricting the regression to OECD countries.

3 Appropriate education systems

Should we conclude from Krueger and Lindahl that education only matters for catching-up but not for innovating at the frontier and that, consequently, education is not an area which Europe needs to reform in order to resume growing at a rate at least equal to that of the US? The new hint at that point came from Acemoglu, Aghion and Zilibotti (2002)'s idea on appropriate institutions and economic growth, and that hint in turn provided the backbone for the Sapir Report and its application to education lead to a report on "Education and Growth" for the French Conseil d'Analyse Economique.

3.1 Acemoglu-Aghion-Zilibotti

By linking growth to innovation and entrepreneurship, and innovation incentives in turn to characteristics of the economic environment, new growth theories made it possible to analyze the interplay between growth and the design of policies and institutions. For example, the basic model developed in Section 2 suggested that long-run growth would be best enhanced by a combination of good property right protection (to protect the rents of innovators against imitation), a good education system (to increase the efficiency of R&D activities and/or the supply of skilled manufacturing labor), and a stable macroeconomy to reduce interest rates (and thereby increase the net present value of innovative rents). Our discussion of convergence clubs in Section 3 then suggested that the

[1] This change was in turn motivated by the so-called Mincerian approach to human capital, whereby the value of one more year in schooling is measured by the wage increase that is foregone by the individual who chooses to study during that year instead of working. This amounts to measuring the value of a human capital stock by the log of the current wage rate earned by an individual. And that log was shown by Mincer to be positively correlated to the number of years spend at school by the individual, after estimating an equation of the form:

$$\ln w = a_0 + a_1 n.$$

The Mincerian approach can itself be criticized, however, for: (i) assuming perfectly competitive labor markets; (ii) ignoring the role of schools as selection devices; (iii) ignoring interpersonal and intertemporal knowledge externalities.

same policies or institutions would also increase a country's ability to join the convergence club.

Now, new growth theories may be criticized by development economists and policy makers, precisely because of the universal nature of the policy recommendations that appear to follow from them: no matter how developed a country or sector currently is, it seems that one should prescribe the same medicines (legal reform to enforce property rights, investment climate favorable to entrepreneurship, education, macrostability,..) to maximize the growth prospects of that country or sector.

However, in his essay on *Economic Backwardness in Historical Perspective,* Gerschenkron (1962) argues that relatively backward economies could more rapidly catch up with more advanced countries by introducing "appropriate institutions" that are growth-enhancing at an early stage of development but may cease to be so at a later stage. Thus, countries like Japan or Korea managed to achieve very high growth rates between 1945 up until the 1990s with institutional arrangements involving long-term relationships between firms and banks, the predominance of large conglomerates, and strong government intervention through export promotion and subsidized loans to the enterprise sector, all of which depart from the more market-based and laissez-faire institutional model pioneered and promoted by the US.

That growth-enhancing institutions or policies might change with a country's or sector's distance to the technological frontier, should not come as a total surprise to our readers at this point: in the previous section, we saw that competition could have opposite effects on innovation incentives depending on whether firms were initially closer to or farther below the fringe in the corresponding industry (it would enhance innovations in neck-and-neck industries, and discourage it in industries where innovating firms are far below the frontier). The same type of conclusion turns out to hold true when one looks at the interplay between countries' distance to the world technology frontier and "openness". Using a cross-country panel of more than 100 countries over the 1960-2000 period, Acemoglu-Aghion-Zilibotti (2002), henceforth AAZ, regress the average growth rate over a five year period on a country's distance to the US frontier (measured by the ratio of GDP per capita in that country to per capita GDP in the US) at the beginning of the period. Then, splitting the sample of countries in two groups, corresponding respectively to a high and a low openness group according to Frankel-Romer's openness indicator, AAZ show that average growth decreases more rapidly as a country approaches the world frontier when openness is low. Thus, while a low degree of openness does not appear to be detrimental to growth in countries far below the world frontier, it becomes increasingly detrimental to growth as the country approaches the frontier. AAZ repeat the same exercise using entry costs to new firms (measured as in Djankov et al (2001)) instead of openness, and they obtain a similar conclusion, namely that high entry costs are most damaging to growth when a country is close to the world frontier, unlike in countries far below the frontier.

More formally, consider the following multi-country growth model. In each country, a unique final good which also serves as numeraire, is produced competitively using a continuum of intermediate inputs according to:

$$y_t = \int_0^1 (A_t\,(i))^{1-\alpha} x_t\,(i)^{\alpha}\;\; di, \tag{1}$$

where $A_t\,(i)$ is the productivity in sector i at time t, $x_t(i)$ is the flow of intermediate good i used in final good production again at time t, and $\alpha \in [0,1]$.

As before, ex post each intermediate good producer faces a competitive fringe of imitators that forces her to charge a limit price $p_t\,(i) = \chi > 1$. Consequently, equilibrium monopoly profits (gross of the fixed cost) are simply given by::

$$\pi_t\,(i) = \delta A_t\,(i)$$

where $\delta \equiv (\chi - 1)\,\chi^{-\frac{1}{1-\alpha}}$.

We still let

$$A_t \equiv \int_0^1 A_t\,(i)\,di$$

denote the average productivity in the country at date t, $\overline{A}_t$ the productivity at the world frontier which we assume to grow at the constant rate g from one period to the next, and $a_t = A_t/\bar{A}_t$ the (inverse) measure of the country's distance to the technological frontier at date t.

Productivity growth occurs as follows. Suppose that intermediate firms have two ways to generate productivity growth: (a) they can imitate existing world frontier technologies; (b) they can innovate upon the previous local technology. More specifically, we assume:

$$A_t\,(i) = \eta \bar{A}_{t-1} + \gamma A_{t-1}, \tag{2}$$

where $\eta \bar{A}_{t-1}$ and γA_{t-1} refer respectively to the imitation and innovation components of productivity growth. Imitations use the existing frontier technology at the end of period $(t-1)$, thus they multiply $\bar{A}_{t-1}$, whereas innovations build on the knowledge stock of the country, and therefore they multiply A_{t-1}.

Now dividing both sides of (2) by $\overline{A}_t$, using the fact that

$$\overline{A}_t = (1+g)\bar{A}_{t-1},$$

and integrating over all intermediate sectors i, we immediately obtain the following linear relationship between the country's distance to frontier a_t at date t and the distance to frontier a_{t-1} at date $t-1$:

$$a_t = \frac{1}{1+g}(\eta + \gamma a_{t-1}). \tag{3}$$

This equation clearly shows that the relative importance of innovation for productivity growth, increases as: (i) the country moves closer to the world technological frontier, i.e as a_{t-1} moves closer to 1, whereas imitation is more important when the country is far below the frontier, i.e when a_{t-1} is close to zero; (ii) a new technological revolution (e.g the ITC revolution) occurs that increases the importance of innovation, i.e increases γ.

This immediately generates a theory of "appropriate institutions" and growth: suppose that imitation and innovation activities do not require the same institutions. Typically, imitation activities (i.e η in the above equation (3)) will be enhanced by long-term investments within (large) existing firms, which in turn may benefit from long-term bank finance and/or subsidized credit as in Japan or Korea since 1945. On the other hand, innovation activities (i.e γ) require initiative, risk-taking, and also the selection of good projects and talents and the weeding out of projects that turn out not to be profitable. This in turn calls for more market-based and flexible institutions, in particular for a higher reliance on market finance and speculative monitoring, higher competition and trade liberalization to weed out the bad projects, more flexible labor markets for firms to select the most talented or best matched employees, non-integrated firms to increase initiative and entrepreneurship downstream, etc. It then follows from equation (3) that the growth-maximizing institutions will evolve as a country moves towards the world technological frontier. Far below the frontier, a country will grow faster if it adopts what AAZ refers to as *investment-based* institutions or policies, whereas closer to the frontier growth will be maximized if the country switches to *innovation-based* institutions or policies. In the remaining part of the paper we simply apply this distinction to education systems.

3.2 Distance to frontier and the composition of education spending

Using the AAZ insight whereby productivity growth can be generated either by implementing (or imitating) the frontier technology or by innovating on past technologies, where both types of activities require different institutions or policies, we will depart from Benhabib and Spiegel by decomposing total human capital stock into primary/secondary and tertiary education, and by arguing that different types of education spending lie behind imitation and innovation activities. In particular, higher education investment should have a bigger effect on a country's ability to make leading-edge innovations, whereas primary and secondary education are more likely to make a difference in terms of the country's ability to implement existing (frontier) technologies. Thus, it is not so much the total *amount* of education, but more importantly the *organization* of education, that impacts on growth differently across countries at different stages of development..

Now, what are the potential implications of this approach for education policy, and is there something to learn from the comparison between Europe and the US given the disappointing news of Krueger and Lindahl from cross-OECD country regressions? The remaining part of the section is based on work by Vandenbussche, Aghion and Meghir (2004) [VAM], and current work by Aghion, Boustan, Hoxby and Vandenbussche (2005) [ABHV]. The starting point of these two papers is that, in contrast to the Nelson-Phelps or Benhabib-Spiegel models, human capital does not affect innovation and imitation uniformly: more specifically, primary/secondary education tends to produce imitators, whereas tertiary (especially graduate) education is more likely to produce innovators. This realistic assumption, in turn, leads to the prediction that, as a country moves closer to technological frontier, tertiary education should become increasingly important for growth compared to primary/secondary education (all measured in stocks).

3.2.1 Solving the Krueger-Lindahl puzzle

First, note that this simple combination of AAZ with the Nelson-Phelps model of education and growth, provides a solution to the Krueger-Lindahl puzzle. Namely, that total human capital stock

$$U + S$$

is not a sufficient statistics to predict growth in OECD countries. For example, take two countries A and B at same distance of world frontier, with same total human capital, but

$$S_A > S_B.$$

Country A will grow faster if the two countries are sufficiently close to frontier whereas country B will grow faster if both countries are far from frontier, and yet the two countries have the same total amount of human capital.

3.2.2 A simple model of appropriate education systems

Now, going in slightly greater details into formalization, VAM and ABHV focus on the following class of productivity growth functions:

$$A_{it} - A_{it-1} = u^{\sigma}_{m,i,t} s^{1-\sigma}_{m,i,t} \bar{A}_{t-1} + \gamma u^{\phi}_{n,i,t} s^{1-\phi}_{n,i,t} A_{t-1} = g(u, s), \tag{4}$$

where $\overline{A}_{t-1}$ is the frontier productivity last period, A_{t-1} is the average productivity in the country last period, u_m (resp. u_n) is the number of workers with primary/secondary education (unskilled workers) used in imitation (resp. innovation), s_m (resp. s_n) is the number of workers with higher education (skilled workers) in imitation, and

$$u = (u_m, u_n); s = (s_m, s_n),$$

and

$$\sigma > \phi$$

so that the elasticity of productivity growth with respect to skilled (resp. unskilled) workers is larger in innovation (resp. in imitation).

Letting $a_t = A_t/\bar{A}_t$ denote the country's proximity to the technological frontier at date t, and letting the frontier grow at constant rate $\overline{g}$, the intermediate producer will choose u and s to maximize profits. Dividing through by $\overline{A}_{t-1}$ and dropping time subscripts, the producer's problem simply becomes:

$$\max_{u_m, u_n s_m, s_n} \{\delta[u^{\sigma}_m s^{1-\sigma}_m + \gamma u^{\phi}_n s^{1-\phi}_n a]\} - w_u(u_m + u_n) - w_s(s_m + s_n)),$$

where we eliminate the firm's subscript i since all intermediate firms face the same maximization problem. Moreover, in equilibrium we necessarily have:

$$u_m + u_n = U; s_m + s_n = S,$$

where U and S are the total supplies of workers with primary/secondary education and tertiary education respectively.

What we have here is formally equivalent to a small open economy model with two factors and two products, where the two products are imitation and innovation, whose prices, δ and $\delta\gamma a$ are exogenously given. As in standard trade theory, these given output prices uniquely determine the equilibrium factor prices w_u and w_s. The "revenue" in firms' objective function is proportional to the growth rate (plus unity). Solving for the equilibrium allocations of skilled and unskilled labor between imitation and innovation as a function of U, S and the proximity a to the technological frontier, one can look at how the equilibrium growth rate

$$g^*(U, S, a) = g(u^*(U, S, a), s^*(U, S, a))$$

varies with either of those three variables.

In particular, looking at the cross derivative of g^* with respect to S and a, we find:

$$\frac{\partial^2 g^*}{\partial a \partial S} > 0;$$

in other words, a marginal increase in the fraction of workers with higher education enhances productivity growth all the more the closer the country is to the world technology frontier.

The intuition for this result relies on the Rybczynski theorem in international trade, which in turn implies that a marginal increase in the supply S of highly educated workers leads to an even greater number of skilled workers being employed in innovation. Since the change does not affect equilibrium factor prices, therefore it leaves the factor proportions unchanged in each activity, meaning that innovation also attracts an increased number of unskilled workers. More precisely, since $\sigma > \phi$, so that innovation is the skill-intensive activity, innovation will increase but imitation will decrease. The effect on firms' "revenue", and hence the effect on the economy's growth rate, is positive. For countries closer to the frontier, where "price" of innovation $\delta\gamma a$ is larger, the effect is larger than for countries further from the frontier.

3.3 Cross-country and cross-US-states evidence

3.3.1 Cross-country evidence

VAM confront this prediction with cross-country panel evidence on higher education, distance to frontier, and productivity growth. ABHV tests the theory on cross-US state data. Each approach has its pros and cons. Cross US-state analysis uses a much richer data set and also very good instruments for higher and lower education spending. However, a serious analysis of the growth impact of education spending across US states, must take into account an additional element not considered in previous models, namely the effects on the migration of skilled labor across states at different levels of technological development. On the other hand, cross-country analysis can safely ignore the migration, however the data are sparse and the instruments for educational spending are weak (they mainly consists of lagged spending). In the remaining part of the section we shall consider the two pieces of empirical analysis in turn.

VAM consider a panel data set of 22 OECD countries over the period 1960-2000, which they subdivide into five year subperiods. Output and investment data are drawn from Penn World Tables 6.1 (2002) and human capital data from Barro-Lee (2000). The Barro-Lee data indicate the fraction of a country's population that has reached a certain level of schooling at intervals of five years, so they use the fraction that has received some higher education together with their measure of TFP (constructed assuming a constant labor share of .65 across country) to perform the following regression:

$$g_{j,t} = \alpha_0 + \alpha_1 dist_{j,t-1} + \alpha_2 \Lambda_{j,t} + \alpha_3 (dist_{j,t-1} * \Lambda_{j,t}) + \upsilon_j + u_{j,t},$$

where $g_{j,t}$ is country j's growth rate over a five year period, $dist_{j,t-1}$ is country j's closeness to the technological frontier at $t-1$ (i.e. 5 years before), $\Lambda_{j,t}$ is the fraction of the working age population with some higher education and υ_j is a country's fixed effect. The closeness and human capital variables are instrumented with their values at $t-2$ and the equation is estimated in differences to eliminate the fixed effect. Before controlling for country fixed effects, VAM obtain a statistically significant coefficient of -1.87 for the human capital variable, and a statistically significant coefficient of 2.37 for the interaction variable, indicating that indeed higher education matters more as a country gets closer to the frontier. Controlling for country fixed effects removes the significance of the coefficients, however this significance is restored once country are regrouped into subregions and country fixed effects are replaced by group fixed effects. This, in turn suggests that cross-country data on only 22 countries, are too sparse for significant regression results to survive when we control for country fixed effects.

To see how this result translates in terms of the effect of an additional year of schooling of higher education, they perform the following regression in logs:

$$g_{j,t} = \alpha_0^{'} + \alpha_1^{'} dist_{j,t-1}^{'} + \alpha_2^{'} N_{j,t} + \alpha_3^{'} (dist_{j,t-1} * N_{j,t}) + \upsilon_j^{'} + u_{j,t}^{'},$$

where this time $dist_{j,t-1}^{'}$ is the log of the closeness to the technological frontier and $N_{j,t}$ is the average number of years of higher education of the population. The econometric technique employed is the same as before. Before controlling for country fixed effects, VAM find the coefficient of the number of years to be 0.105 and of little significance, but the coefficient of the interaction variable to be equal to 0.368 and significant. This result again demonstrates that it is more important to expand years of higher education close to the technological frontier.

3.3.2 Cross-US-states evidence

ABHV test the same theory on cross-US state data instead of cross-country data. As mentioned above, one potential problem when moving from cross-country to cross-region data, is that educational policy should affect migration flows across regions more than it affects migration flows across countries. Thus a suitable model of education and growth across regions within a same country, ought to include an additional equation describing how migration flows varies for example with the wage differential between a particular state and the state currently at the technological frontier. Introducing the possibility of migration reinforces the positive interaction between closeness to the frontier and higher education. Namely, in addition to the Rybczynski effect described above, investing in higher education in a state that is far from the technological frontier, would contribute all the less to growth in that state that the newly skilled workers would migrate to a more frontier state where productivity and therefore wages are higher.

Any regression with growth on the left-hand-side and education on the right-hand-side, raises an obvious endogeneity problem, best emphasized by Bils and Klenow (2000). Here, as in the above cross-country panel regressions, the endogeneity problem can be stated as follows: If states or countries choose their composition of education spending according to the model, then we should see the composition of educational investments being highly correlated with technology and productivity, and therefore the regressions would say nothing about causality.

However, the great advantage of moving from cross-country to cross-state analysis, is that we have access to a natural source of exogenous mistakes in education investment, namely political economy considerations which may lead the congress or other federal instances to misallocate the funding to higher education across states. For example, because it has a representative on a congressional commission for higher education, a far-from-the-frontier state may end up mistakenly receiving excessive funding for research-related education. Conversely, because of local political economy considerations, a close-to-the-frontier state may end up mistakenly focusing its investment in primary education, neglecting higher education.

In other words, political economy considerations and the politicians's ability and incentive to deliver "porks" to their constituencies, provide a natural source of instruments that predict states' tendencies to make exogenous mistakes when investing in education.

The actual instruments used in ABHV are:

1. for Research-University education: whether a state has a congressman on the appropriations committee which allocate funds for research universities but not other types of schools;

2. for "low-brow" post-secondary education (community colleges, training schools): whether the chairman of the state's education committee represents voters whose children attend one- or two-year postsecondary institutions

3. for primary & secondary education: whether the overall political balance on the state's supreme court interacts with the state school finance system.

Then, using annual panel data over the period 1970 - 2000, ABHV perform a two-stage procedure whereby: (i) in first-stage regressions, the various kinds of educational spending are regressed over their respective instruments; (ii) the growth rate in each state and year, is regressed over the instruments for the various kinds of educational spending, the state's proximity to the frontier, and the interaction between the two, controlling for state and year fixed effects.

We refer our readers to ABHV (2005) for the detailed regression results, which yield the following conclusions. First, in contrast to our previous cross-country analysis, here the correlations remain significant even after controlling for state fixed effects without having to regroup the country dummies. Second, the above instruments are very strong, with an F-Statistics of more than 10 for the joint significance of the two dummies for senator and house representative on the corresponding appropriation committees as determinants of research education spending. For example, every additional representative on the House Appropriation committee increases the expenditure on research-type education by $597 per cohort member which is considerable. Now, turning to the second-stage regressions, ABHV find that an additional $1000 per person in research education spending, raises the state's per-employee growth rate by .27% if the state is at the frontier (with a close to 1), whereas it raises it by only 0.09% if the state is far from the frontier (with a close to .3). More generally, the closer a state gets to the technological frontier, the more growth-enhancing it becomes to invest in higher education and the less growth-enhancing it becomes to emphasize lower education.

4 Performance and governance of universities

Following disappointing growth performances in comparison to the US, and to bad Shanghai ranking indicators, several European countries have embarked in national initiatives aimed at improving the foundations and the competitiveness of their national systems of higher education. In some cases this does not go beyond shaking up bureaucratic inertia and approaching the more advanced European models. But there are also cases with elements of general interest, well worth of consideration in a European wide setting.

In particular there is the English reform (it is English because it does not apply to Scotland), with its two main features: an increase of yearly tuition fees (up to a cap of 3000 pounds) and the Graduate Contribution Scheme . There is also the German Excellence Initiative (approved by the Schroeder government) which devotes 1.900 million €, over a period of five years, to a competitive program aimed at generating world class institutions from the matrix of the German universities . And now France is initiating a reform of its university system. After several unsuccessful attempts at implementing radical reforms, France is now taking a more progressive approach which emphasizes universities' autonomy in faculty hiring, leaving aside the delicate issues of students tuitions or student selection.

Is this too little and/or too late? What needs to be done for European universities to catch up with their American counterparts and to contribute more to the growth process in Europe?

Performance of universities is measured by the well-known Shanghai indicator, discussed in detail in Aghion et al (2007). Governance is captured by universities' answers to a questionnaire we designed for this purpose and sent to all 200 European universities among the top 500 universities in the Shanghai ranking, More than one-third of these 200 European universities filled the questionnaire.

Our main findings in Aghion et al (2007) can be summarized as follows: First, there isn't one single model of success in the university sector: The best performers in Europe, which include the UK, Scandinavia and Switzerland, display quite some diversity in terms of both funding and governance. In particular, while the UK, in accordance with expectations, is much more 'market-oriented' than the European average, this is much less true of the other high performers. Our second main finding is that, in general though, good performers are universities which enjoy a higher budget per student as well as higher budget autonomy: Finance and autonomy are therefore complementary inputs to success.

Even though it displays a few cross-sectional regressions, the analysis in Part I of Aghion et al remains essentially descriptive by lack of good panel data involving enough governance variation within each individual country. Thus in Section 4 of that paper, we use panel data on higher education spending and on the governance of universities across US states, to perform a more systematic econometric analysis of the relationship between performance and the spending and autonomy of universities. Performance is measured here by the average patenting rate in a State over a ten-year period. The governance variables are: (i) the share of private universities in the state; (ii) the average degree of autonomy among public universities in the state, itself constructed from a whole set of component measures (hiring autonomy, budget autonomy,...). The main finding in this section is that autonomy and spending are complementary in generating higher growth or higher patenting in the state.

Constructed by a group of Chinese scholars, the Shanghai index puts weights on six subrankings.[2] Table 1 presents a detailed account of cross-country perfor-

[2] The Shanghai index aggregates six subindices:

- The number of alumni from the university winning Nobel Prizes and Fields Medals (this makes for 10% of the overall index).
- The number of university Faculty winning Nobel Prizes in physics, chemistry, medicine, and economics and Field Medals in mathematics (20% of the overall index).
- The number of articles (co-)authored by a university Faculty published in Nature and Science (20% of the overall index).
- The number of articles (co-)authored by a university Faculty published in Science Citation Index-expanded and Social Science Citation Index (20% of the overall index).
- The number of highly cited researchers from the university in 21 broad subject categories (20% of the overall index).

mance comparisons, looking successively at the top 50, the top 100, the top 200, and the top 500 universities in the Shanghai ranking. To better see how to read this table, consider column "Top Y", where Y equals respectively 50, 100, 200 and 500. For each column, the best university in the top-Y group is given grade Y, the next best university is given grade Y-1, and this goes down to grade 1 for the least performing university within that top-Y group. The column "Top Y" shows, for each country (region), the sum of top-Y Shanghai rankings restricted to the Top-Y universities that belong to this country (region), divided by the country's (region's) population. Moreover, all these totals are divided by the number for the US, so that each number can be interpreted as a 'fraction of the US per capita performance".

Several interesting facts come out of this table. First, the US completely dominates among the Top 50, and this is even more true for "university hubs" like Massachusetts (which moreover 'benefits' from its small population). Not surprisingly, there are more zeroes in the top-Y column the lower the Y as it is harder for universities in a country to make it to that group. However, countries and States become more equalized once we enlarge the ranking. In particular the gap between the EU15 or EU25 and the US narrows down as Y increases. Of course, the relative weights allocated to the various universities get also more equalized as Y increases: for example the top Shanghai university gets 50 in the Top 50 and 500 in the Top 500 but the fifty-first university gets zero points in the top 50 but 450 in the top 500. Yet, we see that in all columns with Y equal to 100 or higher, among European countries Switzerland, the UK and Sweden do particularly well, whereas the rest of Scandinavia, Belgium and the Netherlands do pretty well too, but Southern and Eastern Europe always lag behind. Finally, Table 1 shows that the relative performance of EU universities improves as the sample size grows, which in turn suggests that the variance in university performance is lower in Europe than in the US, and it also suggests that what EU countries lack most dramatically are top-class universities.

Now, looking on the input side, Aghion et al (2007) present aggregate data showing that countries with better university performance (e.g the US and Scandinavia) spend more on higher education, with higher budgets per student. How about governance?

A survey questionnaire was sent to the European universities which figured in the Top 500 of the Shanghai ranking in the Fall of 2006. We obtained a response rate of 36%, and focused on the ten countries for which we obtained response rates of at least 25%. While providing a response is not necessarily uncorrelated with university attributes, one can check that for each country, respondents had an average Shanghai rank pretty close to that of the whole population of universities from that country in the ranking (in fact, respondents had a somewhat higher rank for all countries except for Spain).

What do we learn from this questionnaire on how various governance vari-

- The academic performance with respect to the size of the university (10% of the index).

While these weights are admittedly somewhat arbitrary, one advantage they share is their reliance on publicly available information.

ables link to performance? First, private universities tend to perform better than public universities (mixed universities here refer to public universities which own their buildings). Second, universities that set the wages of their Faculty do better than universities that are subject to a centralized wage-setting mechanism. Third, the same is true for universities with hiring autonomy and budget autonomy.

Taken together these figures suggest that the performance of a university is positively affected by all our measures of "autonomy" and also by funding. However, they not tell us: (i) which of these autonomy indicators dominates and how collinear they are; (ii) whether funding and autonomy improve performance in a "separately additive" fashion, or whether we see positive interactions between the two. To answer these questions, Aghion et al first perform a cross-sectional regression of performance over budget and governance variables from the survey. They find a highly significant link between a higher number of students and better performance (that is, a lower rank) picks up a size effect which may be indicative of increasing returns to scale but also of a "Shanghai bias" in favor of large institutions. The link between a higher age and better research performance suggests a cumulative reputation effect, which adds almost 0.20 to the R-square. The link between a higher budget per student and better research performance is also significant, and adds 0.21 to the R-square. Turning to governance variables, they find that only budget autonomy is linked significantly to research performance. The other autonomy variables appear with the anticipated sign (that is, autonomy helps performance) but not significantly. They then rerun the regression concentrating on budget autonomy as sole governance variable, and we see that the various coefficients all remain significant. Then they introduce an interaction between budget autonomy and budget per student. The result indicates having budget autonomy (i.e. going from a value of 0 of the 'budget autonomy' variable to a value of 1) doubles the effect of the "budget per student" variable on the ranking performance of the university.

The main lesson is therefore: budget per student helps research performance, and autonomy doubles this beneficial effect.

Moving from European to US data has one main advantage, namely that we can "instrument" for education spending , in other words we can truly interpret correlations as causalities from education spending to university performance. Another advantage is that for the US we have access to rich cross-state time-varying data set on education spending and patenting across US states over time.

Interestingly, there is also considerable variation in university governance even across neighboring states, even though governance indicators do not vary much over time. For example, universities in Illinois show low autonomy on average, unlike their neighbors in Ohio. These governance differences are persistent over time and they go back to the idiosyncratic origins of American universities. These in turn reflect differences in the preferences of university founders. Thus it is no accident that Benjamin Franklin founded the private University of Pennsylvania whereas Thomas Jefferson founded the public University of Virginia.

Aghion et al to take states' differences in autonomy as given and then ask whether an exogenous investment in higher education produce more patenting in a US state if universities in that state are more autonomous.

For research education they use the detailed time-varying data in Aghion et al (2007a) on how much each state spent on each type of education in all years from 1947 to present. On the governance side, we consider two alternative measures of university autonomy: (i) the percentage of research universities in the state that are private; private universities are indeed more autonomous than any private public university since they would score higher on every measure of financial and academic autonomy; (ii) an aggregate index for public research university autonomy; this index is constructed from a set of component factors listed below.

The aggregate autonomy index takes the maximum value when the public university: (a) sets its own faculty salaries; (b) sets its own tuition; (c) has lump sum budgeting (as opposed to line item budgeting); (d) can shift funds among major categories of expenditure; (e) retains and controls tuition revenue and/or grants; (f) has no ceilings on external faculty positions (it need not hire faculty internally); (g) has no ceilings on external non-faculty positions (administrators or technicians); (h) has freedom from pre-audits of its expenditures; (i) has year-end balances that are carried over (that is, not returned to the state).

The data cover the 1947 to 1972 birth cohorts, and they tell how much each US state spent on each birth cohort in each year. Thus we know how much was spent on average on each individual at every stage of its studies (from primary school to post-graduate college).

Aghion et al then examine the effect on patenting in a US state, of increasing research education funding by $1000 per year and per person in the relevant age cohorts over a six year period, respectively in states with highly autonomous universities and in states with less autonomous universities

At first, when the increase in research education funding is just being introduced, only those cohorts that are about to enter the labor market benefit from the increase in research spending, and therefore the impact on patenting remains small. However, this impact increases as more and more cohorts affected by the spending increase enter the labor market, and it picks when all the cohorts affected by the increase are in the labor market

Now, looking at Figure 1 we see that the accumulated effect of spending on patenting is always significantly higher in states with more autonomous universities than in states with less autonomous universities, and by the same extent in states close to frontier and in states that are far from frontier. That the curves pick lower in the latter case than in the former case, reflects that fact that research spending enhances patenting more in states closer to the frontier, whether universities are more autonomous or not.

5 Conclusion

What have we learned from our discussion in this lecture? First, that capital accumulation-based models have little to say about education policy, particularly with regard to the increasing growth gap between Europe and the US. Second, that Schumpeterian models that emphasize the interplay between human capital stocks and the innovation process, have more potential for delivering policy recommendations, yet when looking at educational spending as a whole there is not much that be said from looking at cross-OECD comparisons.

However, once we distinguish between imitation and frontier innovation and map these two sources of productivity growth to different segments of the education system, then we can come up with relevant policy recommendations for regions like Europe that have moved closer to the frontier and yet are maintaining very low levels of higher education spending compared to the US. The above regressions suggest indeed that putting the emphasis on primary/secondary education was fine as long as Europe was technologically far from the US and therefore relying more on imitation as a main source of growth, but that now that the growth potential of imitation is wearing out, it becomes more urgent to invest more in higher education in order to foster innovation.

What should be done to improve the performance of European universities? First, European countries should invest more in their university systems: on average the EU25 countries spend 1.3% of their GDP on higher education against 3.3% in the US. Thus European countries should increase funding of higher education by at least 1% over the next ten years. A open question remains as to which fraction of the necessary increase in European education funding should be borne by public budgets (tax money) versus tuitions and other sources of private funding. Second, European universities should become more autonomous, in particular on budget decisions, but also on hiring, on wages, on program selection and on student selection, particularly at MA level. A third conclusion, of importance for policy makers, is that while it looks desirable for countries or states to improve on all possible dimensions of autonomy, in countries like France or Italy one can already achieve significant improvements by increasing the budget per student, the budgetary autonomy of universities, and their autonomy in hiring and wage decisions, while postponing the more delicate issues of tuitions and student selection. This in turn suggests a diversity of paths to university reform which are both, efficiency-enhancing and politically feasible.

References

[1] Acemoglu, Daron, Aghion, Philippe, and Fabrizio Zilibotti (2002), "Distance to Frontier, Selection, and Economic Growth", NBER Working Paper No 9066

[2] Aghion, Philippe; Boustan, Leah; Hoxby, Caroline and Jerome Vandenbussche (2005), "Exploiting States' Mistakes to Evaluate the Impact of Higher Education on Growth", mimeo Harvard

[3] Aghion, Philippe and Peter Howitt (1992), "A Model of Growth through Creative Destruction", *Econometrica,* 6*0, 323-351.*

[4] Aghion, Philippe and Peter Howitt (1998), *Endogenous Growth Theory,* MIT Press

[5] Barro, Robert and Jong-Wha Lee (2000),"International Data on Educational Attainment: Updates and Implications", Working Paper No 42, Center for International Development at Harvard University.

[6] Benhabib, Jess and Mark Spiegel (1994),"The Role of Human Capital in Economic Development: Evidence from Aggregate Cross-Country Data", *Journal of Monetary Economics,* 34, 143-173.

[7] Bils, Mark and Peter Klenow (2000), "Does Schooling Cause Growth?", *American Economic Review,* 90, 1160-1183.

[8] Gerschenkron, Alexander (1962), *Economic Backwardness in Historical Perspective,* Harvard University Press.

[9] Ha, Joonkyung and Peter Howitt (2005), "Accounting for Trends in Productivity and R&D: A Schumpeterian Critique of Semi-Endogenous Growth Theory", mimeo Brown University

[10] Krebs, Tom (2003), "Human Capital Risk and Economic Growth", *Quarterly Journal of Economics* 118, 709-44.

[11] Krueger, Alan and Mikael Lindahl (2001), "Education for Growth: Why and For Whom?", *Journal of Economic Literature,* 39, 1101-1136

[12] Lucas, Robert (1988), "On the Mechanics of Economic Development", *Journal of Monetary Economics,* 22, 3-42.

[13] Mankiw, Gregory; Romer, David and David Weil (1992), "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics,* 25, 275-310.

[14] Nelson, Richard and Edmund Phelps (1966), "Investment in Humans, Technological Diffusion, and Economic Growth", *American Economic Review, Papers and Proceedings,* 61, 69-75.

[15] Romer, Paul (1986), "Increasing Returns and Long-Run Growth", *Journal of Political Economy,* 94, 1002-1037

[16] Romer, Paul (1990), "Endogenous Technical Change", *Journal of Political Economy,* 98, 71-102

[17] Sapir, Andre et al. (2003), *An Agenda for A Growing Europe,* Oxford University Press

[18] Vandenbussche, Jerome; Aghion, Philippe; and Costas Meghir (2004), "Growth, Distance to Frontier and the Composition of Human Capital", mimeo Harvard-UCL.